When Training Stops: The Effects of Residency Programs Closure on Mortality Rate

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Abstract

Graduate Medical Education, commonly known as residency training, is crucial for the future healthcare accessibility, especially that shortage of physician is persistant problem in U.S. And is therefore natural to subsidized by the Centers for Medicare and Medicaid Services (CMS). However, research on the effectiveness of residency programs and use of subsidies are limited. This study estimates the closure of residency programs on community-level health outcomes, captured by the mortality rate. Using annual data from the Accreditation Council for Graduate Medical Education (ACGME) matched to county-level healthcare resources and outcomes from the Area Health Resource File (AHRF), we identified counties that experienced residency program closures between 2012 and 2022. Employing the staggered timing of closures, we estimate the dynamic treatment effects using Callaway and Sant'Anna (2021) framework. We find that residency program closures lead to a 1% decrease in mortality rates at the mean, which may be driven by the substitution of residents with non-physician healthcare professionals, such as physician assistants and nurse practitioners.

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1 Introduction

Physician shortages are an ongoing problem in the United states. The Association of American Medical Colleges (AAMC) report estimates that the U.S. faces a significant projected shortage of physicians up to 86,000 by 2036 (GlobalData Plc., 2024). Therefore, it is essential to continue supporting healthcare education. One of the most crucial components of this educational pipeline is residency training, virtually every physician must complete a residency before entering independent practice, making residency positions the major factor in determining the size and distribution of the physician workforce. Physician supply and access to health-care are linked to health outcomes, and the U.S. has a workforce shortage and distributional problem. Physician workforce in the U.S. is shaped by decisions through Graduate medical education (GME). In 2023, the GME Medicare Payments covered 1456 participating sites in a total of 6.3 billion in Direct Graduate Medical Education (DGME) and 15.3 billion in Indirect Medical Education (IME) payments. Therefore, residency programs play an important role in supplying specialized physicians to the health sector labor market, particularly in rural and medically undeserved areas where provider shortages are most pronounced.

A large body of research have examined how disruptions across the healthcare system affect health outcomes. Effective healthcare delivery depends on sufficient infrastructure and trained physicians; a closure of a health providing institution might lead to reduced access to care, longer travel times for patients, and worse health outcomes. The closure of the hospital could lead to reduced access to care for rural residents (Germack et al., 2019; Gujral and Basu, 2019), it can also affect the operational efficiency and quality of nearby hospitals (Song and Saghafian, 2019), hospital closures also can increase the distance patients must travel to receive treatment and, in turn, raise mortality from acute conditions such as heart attacks (Buchmueller et al., 2006). On the other hand, hospitals provide strong economic value to many communities through population and employment (Malone et al., 2022; Alexander and Richards, 2023) and their closure have a direct effect on the decline of jobs within health

sector particularly in rural areas and has no effect on other county-level economic outcomes (Chatterjee et al., 2022). Finally, not all closures have a negative impact, as it can eliminate high fixed costs at the closed facilities (Battaglia, 2025).

Another strand of this literature has examined how the availability of physicians in specific specialties affects mortality, for instance, a higher primary care physicians density is associated with lower mortality (Gujral and Basu, 2019), while the effects can vary across different regions (Ricketts and Holmes, 2007). Additionally, Clay et al. (2025) examine medical school closures and find that they reduce overall mortality, whereas Battaglia (2025) shows that the closure of a specific hospital department, such as a maternity ward, has no detectable effect on infant mortality.

A related line of work considers the changes among residency training programs. Gonzalez et al. (2003) study the family medicine residency programs closures, where they documented the reasons behind closures, including financial pressures, political factors, and institutional leadership changes. Turning to evidence from a policy reform, McNamara and Hussain (2025) show that the affordable care act provisions in 2010 is associated with an increase in residency program size and those changes to GME funding might help in physician shortages.

Despite the main role of the residency programs in the health-care sector, we have limited casual evidence on how change in those training programs affect patient outcome. Existing work has examined medical schools, hospitals, or availability of primary-care physicians to patient outcome and mortality in particular. What remains unclear is how closure of residency training programs affect patients health-outcome.

Our study offers contributions to the body of literature on the impact of physician shortages and health-institution closures. To our knowledge, our study is the first to casually examine the effect of closure of a residency program accredited by The Accreditation Council for Graduate Medical Education (ACGME) — as distinct from a hospital closures — on the mortality rate at the county level, additionally, how the closure of these programs affect the composition of health-workers workforce locally. Two features of residency training make

it central to the question of mortality. First, residents are not merely trainees; they are a current clinical workforce, delivering a share of inpatient care at the teaching and safety-net hospitals. Second, where physicians train strongly predicts where they ultimately practice.

Our findings indicate that the closure of residency programs may lead to a reduction in mortality by 15 per 100,000 population, which represents approximately a 1.3% decrease at the mean. This outcome is primarily attributed to the increase in the number of healthcare providers who are not residents. Specifically, the closure of the program within the county would result in a decreas of 6.6 primary care hospital residents per 100,000 populations, but increase of 3 physician assistants and 6.1 nurse practitioners per 100,000 population, which results overall increase of 2.5 healthcare labor per 100,000 population. However, we find little evidence that closure of residency program would affect number of primary care physicians.

Our results is potentially consistent with the hypothesis that closures affect lower than average rating programs nationwide, and those programs might replace residents with other health-workers, whereas other programs that continue to operate, followed ACGME guideline maintain their practice.

The remainder of this paper is organized as follows. Section 2 provides background information on residency programs. Sections 3 and describe the data and the empirical strategy. The results are presented in section 4. Section 5 presents the results of several robustness checks. Section 6 concludes.

2 Background

Residency programs are the source of specialized trained physicians and play the main role in the supply of the physician workforce. In the United States, residency programs that train physicians are typically funded through graduate medical education (GME) payments, the sponsoring institution, or a combination of both.(U.S. Government Accountability Office, 2021)

Residents enter the training positions through a centralized placement system known as the National Resident Matching Program (NRMP), often known as the Matching System, which annually pairs applicants with those positions within resplendency programs, accepts both graduating medical students and international medical graduates (IMG); each hospital and resident would rank their preferences, once matched, residents begin training that lasts from three to seven years for major specialties and fewer years for fellowships or subspecialties. During this training, residents function as health-care providers, and once the training is completed, they can start private medical practice or work within a health-care institution, with IMG having the opportunity to serve under temporary visas such as the J-1 exchange visitor visa or the H-1B specialty occupation visa. Additionally, IMG can receive a J1-waiver if they practice within designated Health Professional Shortage Areas (HPSAs) or Medically Underserved Areas (MUAs). Such a policy can increase healthcare accessibility and affect the distribution of physicians significantly by specialty (Fink et al., 2003).

Regarding the economics of residency training, institutions that employ residents do not fully bear the cost of training them, the funding source of residency programs is through GME payments. GME funding comes from three main sources: through patient revenue, sponsoring hospital, and mainly from Medicare GME payments, which are provided by the federal government and by far the largest payer. Medicare finances GME through two channels: Direct Graduate Medical Education (DGME) and (Indirect Medical Education)IME, to cover expenses from salaries of residents, attending physicians' reimbursement, and administrative support and infrastructure expenses that can be directly linked to GME initiatives, all the way to other costs related to teaching and the training provided.

This GME funding is closely related to residency program size, and the funding model has remained relatively unchanged over the last two decades, with the system providing incentives to hospitals to focus on resident training and inpatient services (Nuss et al., 2015). Nevertheless, the Affordable Care Act implemented changes to the formula by which teaching hospitals in high-need areas were reimbursed for training residents, which increased the

demand for residents and, in turn, led to an increase in the supply of primary care physicians practicing in those areas (McNamara and Pineda-Torres, 2025). GME funding has generally increased over time, and that growth may reflect an increase in the number of residents. However, even with this increase, the current physician shortfall in the US is expected to worsen (Kirch and Petelle, 2017), particularly for primary care physicians (PCP), because PCPs are relatively underpaid compared with their subspecialty colleagues(Bodenheimer et al., 2007), and many medical students who do enter primary care residencies do not remain in the primary care workforce (Long et al., 2016). Additionally, high levels of medical student debt may influence future career choices away from family medicine and primary care and toward higher-paying specialties (American Medical Association, 2025).

While GME funding is a major source for funding residency programs, the accreditation mechanism determines the operation of such a program. Accreditation Council for Graduate Medical Education (ACGME) is a non-profit organization founded in 1981. It is responsible for evaluating and accrediting residency programs and fellowships, publishing guidelines for sponsors of residency programs, and ensuring compliance with these guidelines. Residency programs that fail to comply will result in probation or withdrawal of accreditation.

The ACGME considers the sponsoring institution responsible for the residency program both financially and academically, examples of sponsoring institutions are a university, medical school, hospital, health department, public health agency, or a school of public health. However, GME Medicare payments are made to participating hospitals, that is, the teaching sites. For each residency program, there will be one sponsoring institution and one or more participating hospitals. While not every residency program is under ACGME accreditation, most non-ACGME programs are sub-specialties that were not accredited yet by ACGME, or advanced programs that do not follow the same process as the accredited one; those non-ACGME residencies do not receive GME Medicare payments, and graduating residents cannot be board certified.

Residency Programs can close while their host hospitals remain open, and hospitals

can close while transferring their programs intact. A closure in the residency programs might be for several reason, it can be due not following the ACGME guidelines in which it results in accreditation withdrawal, or could be related to the teaching hospital financial issue. Any Closure affect the number of healthcare providers within those participating sites, which can affect the health outcome within those locations. The location and number of those programs affect healthcare access through immediate and long-term distribution across different counties. Over the last 15 years, several hospitals, healthcare institutions, and residency programs have experienced closure.

3 Empirical Strategy

3.1 Data

We combine multiple data sources to examine the causal effect of residency program closures on mortality rates and healthcare workforce composition at the county level. Our primary data for residency programs come from the Accreditation Council for Graduate Medical Education (ACGME), which accredits graduate medical education in the United States. In the 2024–2025 academic year, the ACGME accredited 13,762 residency and fellowship nationwide, training 167,083 active residents and fellows.(ACGME, 2025).

The ACGME data includes the list of each program and the characteristics of the those programs, including specialty, number of residents for each program(number of positions filled), sponsoring institution, and geographic information including address and zip code. We matched the program's zipcode with the county, if the zip code belongs to two or more counties, we searched the exact county using the address. Then, we tracked each programs. If the programs were not showing up in the ACGME data for following years, we considered those programs as closed.

One caveat of this approach is that a change in ACGME program code may reflect program restructuring rather than true closure. For example, a program may close under one

ACGME code and reappear in the following year under a new code after being reorganized. To address this issue, we searched for potential restructures among programs with the same sponsoring institution, specialty, and zip code but different ACGME codes. We classified a pair of programs as a restructured candidate if the old code ended before the new code began at the same site, the transition occurred immediately with no gap year, and the old ACGME code disappeared globally before the new code appeared globally. Clean one-to-one restructuring cases were collapsed into a stable program identifier, so that the restructured program was not counted as a closure. Ambiguous restructuring cases, such as cases with multiple possible successors or predecessors, were not collapsed; however, the closure of the old program was suppressed to avoid mechanically treating these cases as closures.

Therefore, our closure measure is intended to capture true program exits while minimizing false closures generated by identifiable ACGME code changes, restructuring, or same-site transitions. In practice, this approach also addresses clean one-to-one merger or restructuring cases when the successor program appears immediately under a different ACGME code with the same sponsoring institution, specialty, and zip code.

However, we cannot fully rule out misclassifications. Mergers or reorganizations that involve changes in sponsoring institution, specialty, or location, that occur with a gap between the old and new program codes, or that involve many-to-one or otherwise ambiguous transitions may not be fully captured by this rule. As a result, some programs that were reorganized or merged outside the observable same-sponsor, same-specialty, same-zip-code structure may still be classified as closures, while ambiguous transition cases may be excluded from the closure measure. So, we also verified each closed program by comparing the list of withdrawn programs from the ACGME website, and we found that all of the closed programs that we defined is matched with the withdrawn programs list but smaller than the total number of withdrawn programs, which indicates that some programs may have been restructured and filed for a new accreditation. According to our data, among Family Medicine and Internal medicine programs, 83.5% of the programs voluntarily withdraw and

16.5% of the programs lose accreditation which matches with the historical data.(Gonzalez et al., 2003)

There are mainly two reasons for program closure that we can classify through the data; voluntary and involuntary loss of accreditation. Voluntary and administrative withdrawal from ACGME accreditation may occur for a variety of reasons, including financial distress (e.g., the 2019 closure of Hahnemann University Hospital (Berns et al., 2020)), no residents enrolled for many years, or restructuring the program (i.e from a hematology program into a hematology and oncology program). On the other hand, Withdrawal of accreditation is involuntary, due to non-compliance reasons, and/or lower quality standards implemented by ACGME accreditation. Voluntary withdrawal of accreditation is the most common reason for program closure, followed by administrative issues and financial problems.

To characterize the hospitals that lost a residency program, we use the Centers for Medicare & Medicaid Services (CMS) Overall Hospital Quality Star Rating, an integer measure from one to five in which higher values denote better performance. We link each closed program to its sponsoring hospital by CMS provider number except for hospitals closed in 2013 because star rating survey was not implemented in 2013. For every matched hospital we record its star rating in the year before closure ($t-1$) and in the closure year itself ($t=0$). We compare each period mean to the national average star rating among all other CMS-rated hospitals over the period from 2014 to 2022. Summary of rating are presented in table A.2. This comparison shows the suggestive evidence that hospitals that lost a residency program had lower star ratings than the national average in both the pre-closure and closure years, with a mean rating of 2.9 stars in the pre-closure year and the closure year, compared to the national average of 3.0 stars. This pattern suggests that hospitals that experienced residency program closures may have been of lower quality than the average hospital, which could have implications for patient outcomes and healthcare access in those communities.

Number of closed programs in each year is described in table A.1. To proceed with our analysis, we restricted the data to residency programs that are directly related to primary

care services. There are two main benefits from restricting our sample. First, residency programs covers a wide range of specialties, and the effect of closure may differ across specialties. Additionally, Family medicine and Internal Medicine are the most common specialties. They constitute 24% or all residency programs, and 35% of total number of resident, 22.6% among closed programs based on our data.

So, we focus on FM/IM programs only since both train physicians to serve as the patient's first point of contact and to provide comprehensive care, and unlike other speciality they are not population specific (i.e. pediatrics), Focusing on these two specialties therefore yields a sample that is most representative of adult primary care.

As the main source of outcome variables, we used Area Health Resource Files(AHRF) county-level aggregated data. AHRF dataset provides various county-level healthcare-related variables, including number of hospitals, number of beds, number of healthcare workers, and mortality rate. We used the mortality rate per 1,000 population as our main outcome variable. We also used inpatient days per 1,000 population and total inpatient beds per 1,000 population, outpatient visit ratio as additional outcome variables to check whether residency program closures affect healthcare utilization that might be related to the change in mortality rate.

Next, to explore mechanism further, we used the healthcare spending variables from United State Health Care Spending by Health Condition and County 2010-2019 from Institute for Health Metrics and Evaluation (IHME) (2025). This dataset was collected with the Disease Expenditure Project (DEX) at IHME which produced estimates for US spending on healthcare across counties by health condition, payer type, type of care and age group from 2010 to 2019. From this dataset, we selected a small set of measures that would be related to the change in mortality rate and mainly driven by inpatient care and preventive care utilization, additionally those conditions outcomes are responsive to the accessibility and quality of physician care. (Agency for Healthcare Research and Quality, 2001) identifies this set which include Asthma, Chronic Obstructive Pulmonary Disease (COPD), Type 2 Diabetes, Heart

Failure, Hypertensive Heart Disease, Treatment for Hypertension, and Treatment for Hyperlipidemia. Preventable hospitalization and death for such conditions are long-established markers of primary care access (Laditka et al., 2005), and greater primary care physician supply is associated with lower cardiovascular and respiratory mortality across U.S. counties (Basu et al., 2019). We also scaled spending measures by 1,000 population and adjusted with 2020 CPI. Total spending captures total spending for these conditions, regardless of the type of care. Also, we separately aggregated spending for Inpatient care, Emergency Department and Retail Pharmacy, which are the main types of care that may be affected by the change in healthcare workforce composition after residency program closures.

3.2 Identification and Estimation

We exploit variation in the timing of residency program closures across counties using the staggered difference-in-differences framework of Callaway and Sant'Anna (2021). The unit of analysis is the county-year. Let $G_c = g$ indicate that county c first experiences a residency program closure in year g, and let $G_c = \infty$ denote counties that do not experience a closure during the sample period. Once a county experiences its first closure, it is treated as exposed in all subsequent periods. Our baseline comparison group consists of counties that are never treated during the sample period.

$$\begin{aligned} ATT(g,t) &= \mathbb{E}[Y_{ct}(g) - Y_{ct}(0) | G_g = 1, X_c] \\ &= \mathbb{E}[Y_{ct} - Y_{cg-1} | G_g = 1, X_c] - \mathbb{E}[Y_{ct} - Y_{cg-1} | C = 1, X_c], \end{aligned}$$

where $Y_{ct}(g)$ is the potential outcome for county c, at year t if the county first experiences a residency program closure in year g. We are using never treated unit as control C. X_c includes county level covariates, including number of hospitals per 1,000 population, number of beds per 1,000 population, log of median income(adjusted with 2020 CPI), unemployment

rate(BLS), ratio of older adults, female, black, hispanic, asian or pacific islanders and uninsured in year 2012. We fixed the time of the covariates at the pre-treatment level for all treated units, which is our start year, 2012, to avoid any post-treatment bias.

We estimate group-time average treatment effects, $ATT(g,t)$, using a doubly robust difference-in-differences estimator (Sant'Anna and Zhao, 2020). The estimator combines outcome regression and propensity score weighting for robustness to estimate treatment effects for counties first experiencing residency program closure in year g and observed in year t. To assess robustness, we estimate the main specifications both with and without county-level covariates.

We then aggregate $ATT(g,t)$ across groups and the post-treatment periods to obtain the overall average treatment effect on the treated (ATT). Then, the aggregated $ATT(g,t)$ is shown as:

$$ATT(g,t) = \mathbb{E}[Y_t - Y_{g-1} \mid G_g = 1] - \mathbb{E}[Y_t - Y_{g-1} \mid C = 1].$$

We also examine the dynamic effects of residency program closures on mortality and healthcare utilization. The effect of a closure may evolve over time, as healthcare providers, patients, and local healthcare organizations adjust to changes in residency training capacity. For example, the immediate effect of a closure may differ from the longer-run effect if workforce composition, care coordination, or patient-provider relationships adjust gradually after the closure.

To study these dynamics, we estimate the event-study parameters by aggregating the group-time average treatment effects, $ATT(g,t)$, by the event time. Let $e = t - g$ denote the event time relative to the closure year, and let $\mathcal{G}$ denote the set of treatment cohorts. The event-study parameter is defined as:

$$\theta_{es}(e) = \sum_{g \in \mathcal{G}} \mathbf{1}\{g + e \in \mathcal{T}\} P(G = g \mid g + e \in \mathcal{T}) ATT(g, g + e), \tag{1}$$

where $\mathcal{T}$ denotes the set of observed time periods. This parameter averages the group-time

treatment effects for counties observed at event time e, weighting each treatment cohort by its relative size among cohorts observed at that event time.

4 Results

Our main findings are presented in Table 1 to Table 4. We begin by examining the effect of residency program closures on mortality rate and other healthcare utilization measures, and we will analyze for how these effect differs by different subgroups. Finally, we explore potential mechanisms by analyzing changes in local healthcare workforce composition following residency program closures and by examining the changes in healthcare spending across conditions and the types of care.

Table 1 presents estimates of the effect of the residency program closures on mortality and healthcare utilization. In the specification with county-level controls, residency program closures reduce mortality by 0.150 deaths per 1,000 population, equivalent to 15 deaths per 100,000 population. Relative to the pre-treatment mean of 10.979 deaths per 1,000 population, this corresponds to a 1.37% decrease in mortality.

In contrast, we find no statistically significant effects on total inpatient admissions or outpatient visits. We find, however, that inpatient days per patient per week increase following the residency program closures. With county-level controls, inpatient days per inpatient increase by 0.197 days per week. Relative to the mean of 2.339, this represents an 8.4% increase. This result indicates that, conditional on inpatient admission, patients spend more time in inpatient care after residency program closures, even though the number of inpatient admissions do not change significantly. This pattern may reflect more intensive inpatient treatment among admitted patients, longer stays due to discharge delays or care coordination frictions, or workforce constraints following residency program closures. However, because the inpatient-days result is less robust across specifications, it should be interpreted with caution.

[Table 1 here.]

Figure 1 presents event-study estimates for mortality and healthcare utilization. Across outcomes, the pre-treatment estimates are generally centered around zero, providing little evidence of differential pre-trends prior to residency program closures. The dynamic estimates show a gradual decline in mortality following residency program closures. Although the estimates become less precise in later period due to smaller sample size with later treated units, the post-treatment coefficients are consistently negative and grow in magnitude over time, suggesting that the mortality effect emerges gradually rather than immediately.

For healthcare utilization, the event-study estimates suggest changes in the composition of care rather than a large change in overall utilization. Outpatient visits increase after closure, with the post-treatment coefficients becoming more positive over time, although the estimates are imprecise. Total inpatient admissions, in contrast, do not show a clear increase immediately after closure and are close to zero or slightly negative in the early post-treatment periods. At the same time, inpatient days per admitted patient increase in the first several post-treatment periods. This pattern suggests that, conditional on admission, patients may spend more time in inpatient care after residency program closures.

Taken together, the event-study results are consistent with a shift in the delivery of care after residency program closures: outpatient care appears to increase, inpatient admissions do not increase substantially, and admitted patients appear to remain hospitalized for longer in the short to medium run. However, the increase in inpatient days should be interpreted cautiously, as it is not robust across all specifications and does not by itself distinguish between more intensive inpatient treatment and longer stays due to discharge delays, care coordination frictions, or workforce constraints.

[Figure 1 here.]

4.1 Heterogeneity Analysis

Table 2 examines whether the effects of residency program closures differ across counties with different baseline characteristics. We stratify counties by baseline Social Vulnerability Index (SVI) and 2010 Median income. SVI is a composite measure of social vulnerability that captures factors such as socioeconomic status, household composition, minority status, and housing type, which may have different effects of residency program closures. For instance, more socially vulnerable counties may have a fewer healthcare resources and a greater healthcare needs, or might experience larger marginal benefit from preventive care utilization. Which may be the case when the closure of a residency program may have a larger impact on healthcare access and outcomes in these areas. On the other hand, less socially vulnerable counties may have more resources and better access to care, which could mitigate the effects of residency program closures.

We also divide counties by 2010 median age, since the effects may differ between counties with older and younger baseline population age structures. Because older populations have higher baseline mortality risk and greater healthcare needs, residency program closures may have different effects in counties with higher median age. We use these two measures to explore whether the effects of residency program closures differ across counties with different levels of social vulnerability and healthcare spending intensity.

Panel A stratifies counties by 2010 SVI. The estimated mortality effect is negative in both high- and low-SVI counties. Closure of residency program could decrease 9.2 deaths per 100,000 population among high-SVI counties and 1.93 deaths per 100,000 population among low-SVI counties. The larger mortality reduction among low-SVI counties may reflect greater local capacity to adjust to residency program closures although we controlled for number of hospital and number of beds per 1,000 population, which is a common measure for healthcare access. Less socially vulnerable counties may be better able to substitute toward NPs, PAs, or other providers and to translate workforce changes into timely care, care coordination, or chronic disease management. In high-SVI counties, social and structural barriers may

limit the extent to which similar workforce adjustments improve outcomes. Because the SVI analysis does not directly measure these mechanisms, we interpret this pattern as suggestive rather than causal evidence.

Panel B divides counties by 2010 median age. Mortality rate is higher in older counties, with 12.15 deaths per 1,000 population compared to 9.81 in younger counties. The estimated mortality effect is negative in both groups. Among older counties, residency program closures are associated with a reduction of 51.6 deaths per 100,000 population, which corresponds to a 4.24% reduction. Among younger counties, the estimated reduction is smaller, at 15.8 deaths per 100,000 population, which corresponds to a 1.6% reduction. Similar to the SVI stratification, we find no clear pattern in the effects on healthcare utilization across age groups.

Taken together, the SVI and the median-age heterogeneity results suggest that the mortality reductions are not confined to counties with a single baseline profile. The larger estimate among the low-SVI counties may reflect greater local capacity to adjust to residency program closures, while the larger point estimate among older counties is consistent with the possibility that mortality in older populations is more sensitive to changes in timely care and chronic disease management. However, because these subgroup analyses do not directly measure the access to timely care, preventive service use, or the care coordination due to data limitations, we interpret this pattern as suggestive evidence.

[Table 2 here.]

4.2 Mechanism

To explore the potential mechanisms behind the reduction in mortality following residency program closures, we examine whether closures are associated with changes in healthcare workforce composition at the county level. We first analyze changes in the number of Family Medicine and Internal Medicine residents per 1,000 population. As an alternative measure of residency training capacity, we also use the number of primary care residents per

1,000 population from the Area Health Resources File (AHRF). We then examine whether closures are followed by changes in other components of the healthcare workforce, including nurse practitioners (NPs), physician assistants (PAs), and primary care physicians per 1,000 population. Finally, we examine payroll expenditure as a proxy for changes in labor costs.

The results are presented in Table 3. Residency program closures are associated with a reduction in the resident workforce. The number of Family Medicine and Internal Medicine residents decreases by 0.038 per 1,000 population. Using the AHRF measure, the number of primary care residents decreases by 0.066 per 1,000 population, indicating that the closure measure captures a reduction in local residency training capacity. The larger decline in the AHRF primary care resident measure may reflect the fact that this measure captures broader county-level primary care residency capacity than our program-level FM/IM measure. In addition, FM/IM closures may occur as part of broader hospital- or system-level contractions in graduate medical education, in which multiple residency programs or primary-care-related training slots are reduced around the same time. We therefore interpret the AHRF measure as evidence of broader local reductions in primary care residency capacity.

At the same time, closures are followed by increases in some non-resident healthcare workforce categories. The number of nurse practitioners (NP) increases by 0.062 per 1,000 population, and the number of physician assistants (PA) increases by 0.030 per 1,000 population. Relative to the pre-treatment means, these estimates correspond to increases of approximately 10.6% for NPs and 10.5% for PAs. However, we find little evidence of a change in the number of primary care physicians per 1,000 population.

These results suggest that residency program closures may be followed by partial substitution toward other healthcare workers, especially NPs and PAs. A simple exercise illustrates the magnitude of this compositional shift. The estimated decline in primary care residents is 6.6 per 100,000 population, while the combined estimated increase in NPs and PAs is 9.1 per 100,000 population. This implies a net increase of approximately 2.5 providers per 100,000 population, which suggests that the reduction in resident labor may be more than offset by

the increases in other healthcare workers. This compositional shift may reflect adjustments in local healthcare labor markets following residency program closures, as healthcare organizations respond to changes in training capacity and workforce availability by hiring more NPs and PAs.

We also examine payroll expenditure to assess whether these workforce changes are associated with changes in labor costs. The estimated effect on payroll expenditure is positive but small and statistically insignificant. This result does not provide evidence of a large increase in payroll expenditure following residency program closures. One possible interpretation is that reductions in resident labor are partially offset by increases in other healthcare workers, leaving aggregate payroll expenditure relatively unchanged.

Overall, the workforce results are consistent with a compositional adjustment in the local healthcare workforce after residency program closures. Closures reduce the number of residents, while counties experience increases in NPs and, to a lesser extent, PAs. This pattern provides suggestive evidence that changes in workforce composition may be one channel through which residency program closures affect patient outcomes and reducing mortality. However, these estimates should be interpreted as mechanism-supporting evidence rather than definitive proof of the causal pathway linking closures to mortality reductions.

We also suggest that we cannot find the evidence for significant increase for the payroll expenditure, which may suggest that the increase in more experienced healthcare professionals may be offset by the decrease in residents, who typically have lower salaries. However, changes in payroll expenditure is not statistically significant, which may indicate that the cost savings from reducing the number of residents may be roughly balanced by the increased costs of hiring more experienced healthcare professionals. Our result support the recent studies with Nurse Practitioners (NP) and Physician Assistants(PA), which show that they can provide high-quality care and improve access to healthcare services.

A large body of evidence indicates that this substitution does not necessarily lower quality of health services provided. In randomized and large administrative-data studies, pa-

tients managed by NPs and PAs obtain health outcomes comparable to those managed by physicians, (Everett et al., 2019; Jackson et al., 2018; Yang et al., 2018) find no significant differences in diabetes patients outcomes. Everett et al. (2013) and Virani et al. (2016) find comparable health outcome in blood pressure and cardiovascular disease (CVD) between NP, AP, and MD. Aditionally, Yang et al. (2023) and Muench et al. (2019) study NP quality of care through health care utilization and quality of primary care that patients receive from NPs or other providers, and find lower ED visits and lower office-based and specialty care costs by NP.

[Table 3 here.]

[Figure 2 here.]

Next, we examine downstream healthcare spending to further explore potential mechanisms behind the reduction in mortality. In addition to changes in healthcare workforce composition, residency program closures may affect patient outcomes by changing the type of care patients receive. We therefore examine spending for conditions that are commonly managed in primary care and may lead to inpatient care if poorly controlled, including asthma, chronic obstructive pulmonary disease (COPD), type 2 diabetes, heart failure, hypertensive heart disease, hypertension, and hyperlipidemia. We also examine spending by type of care, distinguishing total spending, inpatient spending, emergency department spending, and retail pharmacy spending. Due to data availability, the spending analysis is limited to the period from 2010 to 2019.

Table 4 reports the effects of residency program closures on spending by type of care, aggregated across the included conditions. We do not find statistically significant changes in spending regaring all types of care. Figure 3 may suggest that the pattern of spending changes may differ by type of care. We didn't find a clear pattern in total spending, but in inpatient spending and ed spending, we see a short reduction in spending in the first several post-treatment periods, which may reflect a reduction in inpatient care or emergency

department visits following residency program closures. In contrast, retail pharmacy spending appears to increase after closure, with the post-treatment coefficients becoming more positive over time, although the estimates are imprecise. This pattern may reflect a shift toward outpatient management and greater reliance on medications following residency program closures. However, given the imprecision of these estimates and the lack of statistically significant effects in the main table, we interpret these patterns as suggestive rather than definitive evidence of changes in care patterns following residency program closures.

[Table 4 here.]

[Figure 3 here.]

5 Robustness Checks

Table 5 to table 9 show the results of several robustness checks. First, we change the definition of treatment or sample to avoid any selection bias from choosing treatment or sample. And we changed the estimation method to check the robustness of our results.

In table 5, we restrict the sample to counties that are at risk of experiencing a residency program closure, defined as counties that had at least one residency program in 2012. This restriction addresses the concern that including counties without any residency programs may dilute the estimated effects of closures, as these counties would not be directly affected by closures. The results in this at-risk sample are qualitatively similar to our main analysis, with residency program closures associated with reductions in mortality and changes in healthcare utilization patterns for mortality, however we didn't find significant increase in inpatient utilization.

[Table 5 here.]

Second, while our main analysis tracks individual residency program closures, such closures may not correspond to a meaningful reduction in local training capacity if they are

offset by openings or expansions of other programs within the same county. We therefore conduct a robustness check using an alternative treatment definition based on net reductions in the number of residency programs at the county level. The results remain qualitatively similar, indicating that our findings are robust to focusing on closures that translate into a net decline in county-level residency training capacity.

[Table 6 here.]

We could also be concerned about treatment selection, where we choose to focus on Family Medicine and Internal Medicine residency program closures, which may not capture the full extent of reductions in local residency training capacity. To address this concern, we changed a treatment definition to include all residency program closures regardless of specialty and broader definition of primary care physicians including pediatrics, obstetrics/gynecology and emergency medicine. Table 7 shows the estimates with different treatment definitions. Panel A shows the results for all core program closures, while Panel B shows the results for the broader definition of primary care physicians, which includes pediatrics, obstetrics/gynecology and emergency medicine in addition to the family medicine and internal medicine programs. The results remain consistent with our main findings, indicating that our estimates are not sensitive to the specific treatment definition used.

[Table 7 here.]

Also, COVID-19 pandemic may have affected the healthcare system and healthcare utilization patterns, which may confound our estimates if the timing of residency program closures coincides with the pandemic. To address this concern, we conducted a robustness check by restricting our sample to the pre-pandemic period (2010-2019). The results remain consistent with our main findings, suggesting that our estimates are not driven by changes in healthcare utilization patterns during the COVID-19 pandemic.

[Table 8 here.]

Although our estimator includes propensity score weighting to adjust for differences in observable characteristics between the treated and control groups, we further conducted a robustness check using matched sample. We used propensity score matching (PSM) prior to estimating the average treatment effect. We matched treated counties with control counties based on their propensity scores, which were estimated using a logit model that included relevant covariates, such as number of hospitals per capita, number of beds, median income, unemployment rate, and demographic factors that are identical set as we included in covariates in Table 1. Table B.1 shows the covariate balance before and after matching, indicating that the matching process effectively reduced differences between treated and control groups. We matched each treated county with eight control counties using nearest-neighbor matching with replacement. The 8:1 matching ratio was selected because it minimized the maximum absolute standardized mean difference across the baseline covariates among the candidate ratios considered.

Table 9 present the results using the PSM approach. The results remain consistent with our main findings, showing a significant reduction in mortality rates following residency program closures, while the effects on inpatient days and total inpatient with beds set up remain statistically insignificant. Additionally, we observed similar patterns in the physician labor market, with increases in the number of physician assistants, nurse practitioners, and physicians with M.D. degrees.

[Table 9 here.]

6 Conclusion

Community health is a public good, and residency training programs play a crucial role in shaping the pipeline for the healthcare workforce. Substantial Medicare funding is allocated to support graduate medical education, yet there is limited evidence on the efficiency of residency programs or the benefits of residency training itself. This paper provides new

evidence on this question by examining the effects of family medicine and internal medicine residency program closures on county-level mortality, healthcare utilization, and healthcare workforce composition.

Using annual ACGME program data matched to multiple county level datasets, we find that closures of family medicine and internal medicine residency programs are associated with a reduction in mortality rates. At the same time, we find limited evidence that residency program closures lead to large changes in overall healthcare utilization. However, these findings should not be interpreted as evidence that residency program closures are desirable or that reducing physician training capacity improves population health. Rather, our results suggest that local healthcare systems may adjust to program closures by reorganizing the composition of the healthcare workforce. As one potential mechanism, we find that residency program closures increases the number of physician assistants and nurse practitioners, with no decline in the number of primary care physicians with M.D. degrees. This pattern suggests that local healthcare systems may respond to residency program closures by substituting toward non-physician clinicians.

However, these estimates capture adjustments within the observed post-closure timeline and should not be interpreted as evidence on the long-run consequences of reducing residency training capacity. Because physician training takes several years, the long-run effects of residency program closures on the physician pipeline, specialty composition, and geographic distribution of clinicians may differ from the effects observed in this study. Future research could examine the longer-run consequences of residency program closures for healthcare workforce composition, patient outcomes, and healthcare utilization to better understand the full implications of such closures for local healthcare systems and population health.

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Tables and Figures

Figure 1: Event Study of Residency Program Closures on Mortality Rate and Healthcare Utilization

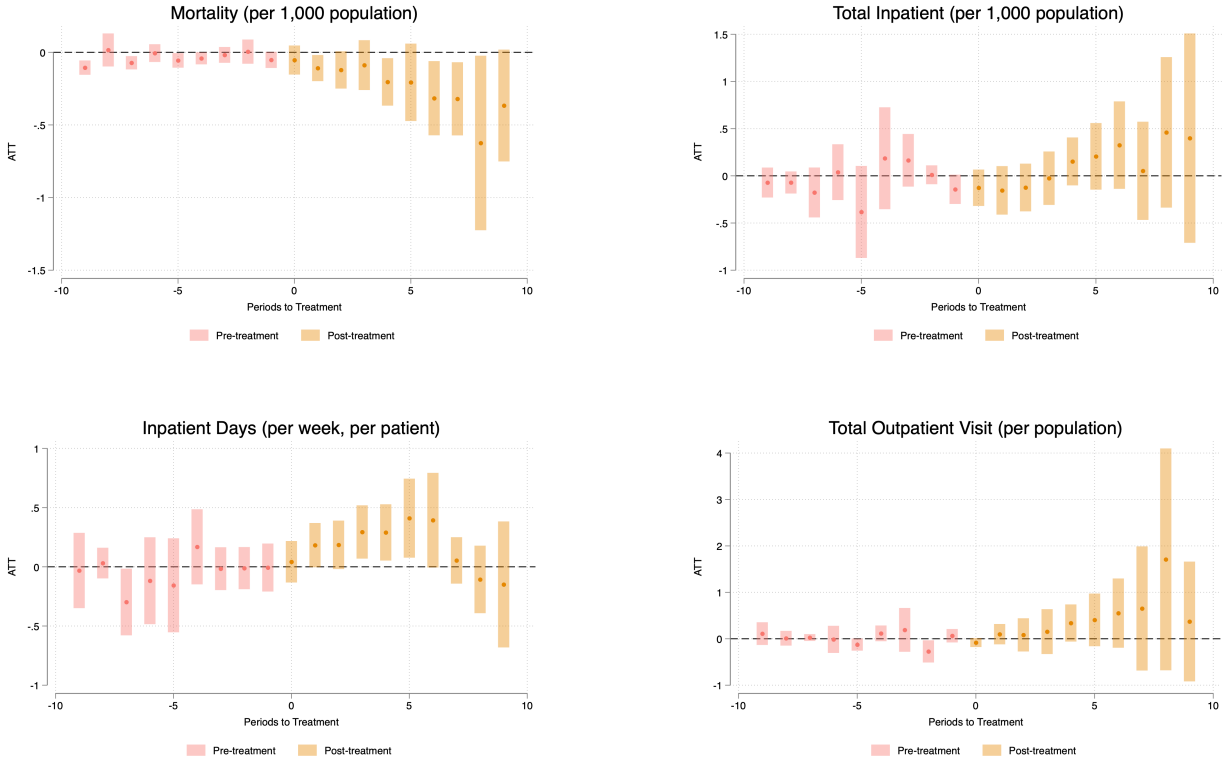


Figure 2: Event Study for Residency Program Closures on Healthcare Workforce

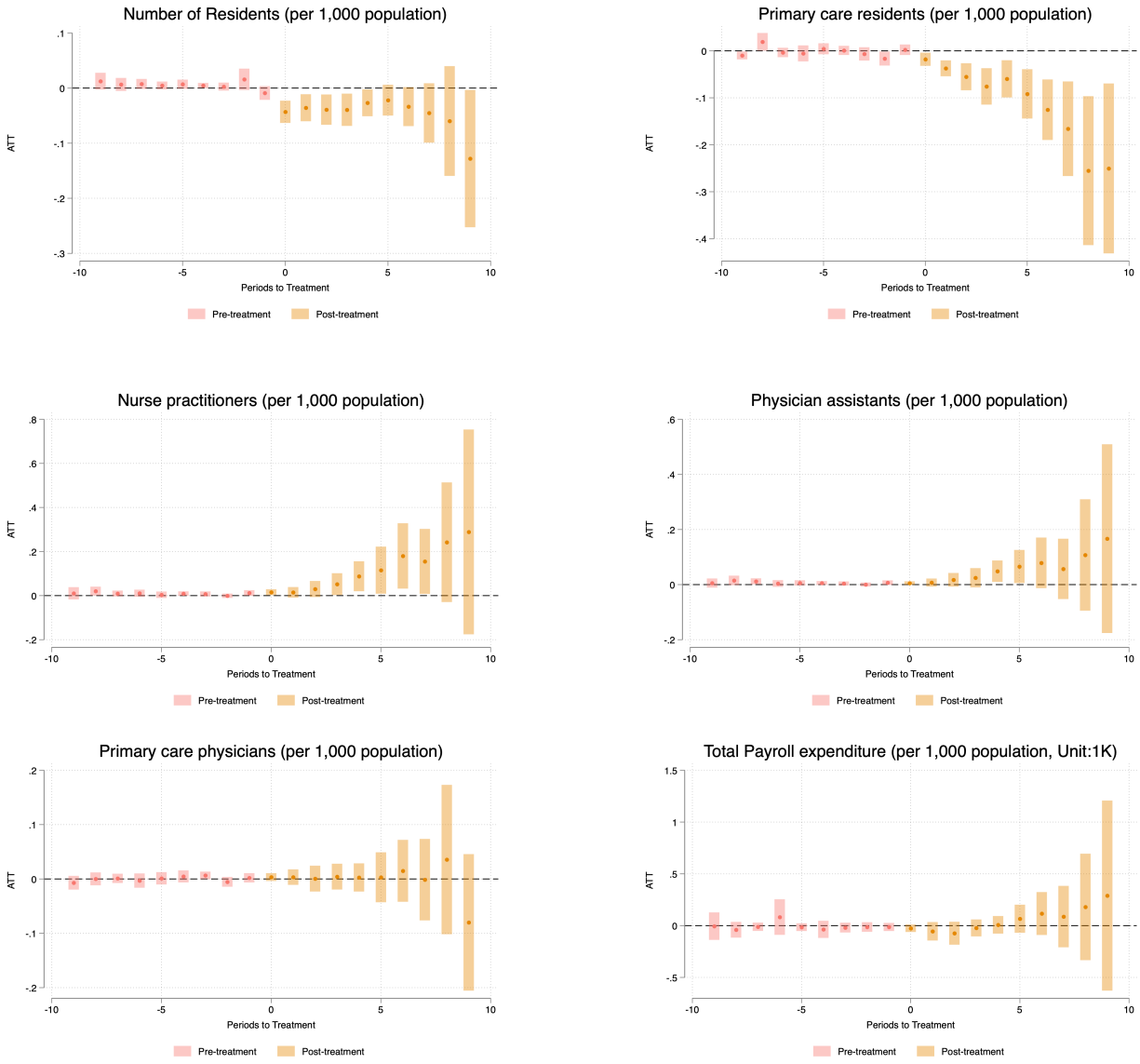


Figure 3: Event Study for Residency Program Closures on Healthcare Workforce

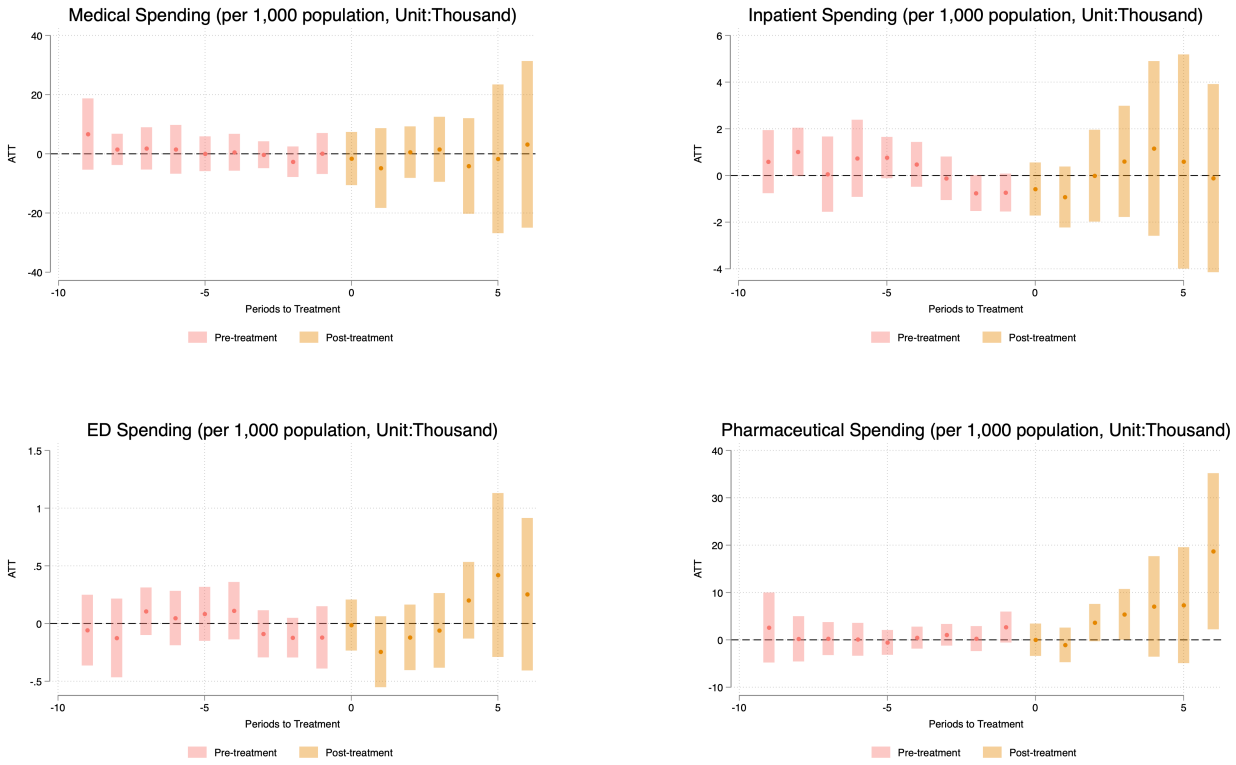


Table 1: Effects of Residency Program Closures on Mortality and Healthcare Utilization

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
ATT	-0.57950***	-0.15001***	-0.07214	-0.00796	0.38614**	0.19749**	0.15717	0.20616
	(0.05453)	(0.04210)	(0.14500)	(0.12330)	(0.15007)	(0.09694)	(0.17417)	(0.17455)
Mean of Dependent Variable	10.979		2.384		2.339		2.526	
Observations	34518	34507	34518	34507	34518	34507	34518	34507
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
Mortality and total inpatient are per 1,000 population. Outpatient visits are measured per population. Inpatient days are divided by 52 to convert annual measures to weekly measures and divided by number of patients. Inpatient costs are adjusted using the 2020 CPI.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

Table 2: Heterogeneous Effects of Residency Program Closures on Mortality Rate and Healthcare Utilization

	(1) Mortality	(2) Total Inpatient	(3) Inpatient Days	(4) Total Outpatient Visit
Panel A: Social Vulnerability Index				
High SVI	-0.09207*	0.06165	0.10889	0.18805
	(0.05174)	(0.12332)	(0.10765)	(0.17693)
Mean of Dep. Var.	11.371	2.276	2.435	2.439
Observations	17,248	17,248	17,248	17,248
Low SVI	-0.19274***	0.05699	0.22189	0.57093
	(0.07177)	(0.12881)	(0.14630)	(0.45775)
Mean of Dep. Var.	10.582	2.487	2.244	2.611
Observations	17,237	17,237	17,237	17,237
Panel B: Median Age				
Older Counties	-0.51632*	-0.20930	-0.33188	0.02481
	(0.29012)	(0.25817)	(0.28244)	(0.09318)
Mean of Dep. Var.	12.150	2.540	1.994	2.438
Observations	17,193	17,193	17,193	17,193
Younger Counties	-0.15809***	0.01909	0.19387**	0.23259
	(0.04315)	(0.11193)	(0.09878)	(0.17736)
Mean of Dep. Var.	9.813	2.222	2.681	2.612
Observations	17,292	17,292	17,292	17,292

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All coefficients reported are simple average of group-time average treatment effects(ATTs).

Mortality and total inpatient are per 1,000 population. Outpatient visits are measured per population. Inpatient days are divided by 52 to convert annual measures to weekly measures and divided by number of patients. Inpatient costs are adjusted using the 2020 CPI.

County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic, % asian, % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012.

Counties are divided into high- and low-SVI groups and high- and low-median age groups based on whether their 2010 SVI and median age are above or at/below the sample median, respectively.

Table 3: Effects of Residency Program Closures on Healthcare Workforce

	(1) FM/IM Residents	(2) Primary Care Residents	(3) NP	(4) PA	(5) PCP Physicians	(6) Payroll Expenditure
ATT	-0.03777***	-0.06646***	0.06172**	0.03015*	0.00349	-0.00606
	(0.01185)	(0.01377)	(0.02640)	(0.01716)	(0.01107)	(0.04281)
Observations	34507	34507	34507	34507	34507	34507
Mean of Dependent Variable	0.034	0.028	0.582	0.287	0.448	0.851
County Level Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population, number of beds per 1,000 population.
All outcome variables are per 1,000 population. Payroll expenditure is inflation adjusted with 2020 CPI. Column (1) is a direct measure of the number of residents with specialized in Family Medicine and Internal Medicine. From Column (2) to Column (6) are from AHRF dataset.

Table 4: Effects of Residency Program Closures on Medical Spending by Types of Care

	(1) Total Spending	(2) Inpatient Spending	(3) ED Spending	(4) Retail Pharmaceutical Spending
ATT	-1.66955	-0.17317	-0.04757	2.51322
	(4.41094)	(0.80737)	(0.10904)	(1.88009)
Mean of Dependent Variable	191.199	6.089	2.173	100.117
Observations	25096	25096	25096	25096
County Level Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
Outcomes are per 1,000 population and adjusted with 2020 CPI. Unit is $1,000. Total spending captures total spending for these conditions, regardless of the type of care. Inpatient care includes spending for inpatient care only, emergency department includes spending for emergency department visits only, and retail pharmacy includes spending for retail pharmacy only.
Included conditions are asthma, chronic obstructive pulmonary disease (COPD), type 2 diabetes, heart failure, treatment for hypertension, and treatment for hyperlipidemia. All spending measures are per 1,000 population and adjusted with 2020 CPI. Total spending captures total spending for these conditions, regardless of the type of care. Inpatient care includes spending for inpatient care only, emergency department includes spending for emergency department visits only, and retail pharmacy includes spending for retail pharmacy only.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

Table 5: Effects of Residency Program Closures: At-Risk Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
ATT	-0.20887***	-0.09433**	-0.22042	-0.22813**	0.05274	0.02787	-0.18774	-0.16771
	(0.05474)	(0.04729)	(0.14101)	(0.09825)	(0.06577)	(0.06367)	(0.13740)	(0.14959)
Observations	4742	4742	4742	4742	4742	4742	4742	4742
Mean of Dependent Variable	9.751		3.019		4.059		3.897	
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
All outcome variables are per 1,000 population except for the outpatient visits, which are per population. Inpatient days are divided by 52 to convert from per week to per year. Inpatient cost is adjusted with 2020 CPI.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

Table 6: Effects of Residency Program Closures: Net decrease in Residency Programs at County Level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
ATT	-0.68687***	-0.15875***	-0.13093	-0.14738	0.20757*	0.01608	-0.02451	0.02037
	(0.05730)	(0.04980)	(0.14405)	(0.13414)	(0.12055)	(0.07647)	(0.14212)	(0.12725)
Mean of Dependent Variable	10.979		2.384		2.339		2.526	
Observations	34485	34485	34485	34485	34485	34485	34485	34485
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
All outcome variables are per 1,000 population except for the outpatient visits, which are per population. Inpatient days are divided by 52 to convert from per week to per year. Inpatient cost is adjusted with 2020 CPI.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

Table 7: Effects of Residency Program Closures: Different Treatment Definitions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. All closures								
ATT	-0.57970***	-0.18218***	0.04297	0.16818	0.30729***	0.17598**	0.14049	0.25021**
	(0.03747)	(0.03267)	(0.09773)	(0.12631)	(0.08855)	(0.08378)	(0.10154)	(0.10964)
Panel B. Broader PCP closures								
ATT	-0.53308***	-0.10627**	-0.03784	0.01731	0.34649***	0.17980**	0.18287	0.21140
	(0.05670)	(0.04194)	(0.11514)	(0.10040)	(0.12107)	(0.07831)	(0.14924)	(0.15163)
Mean of Dependent Variable	10.979		2.384		2.339		2.526	
Observations	34518	34507	34518	34507	34518	34507	34518	34507
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
Mortality and total inpatient are measured per 1,000 population. Outpatient visits are measured per population. Inpatient days are divided by 52 to convert annual measures to weekly measures and divided by the number of patients. Inpatient costs are adjusted using the 2020 CPI.
County-level controls include log median income adjusted using the 2020 CPI, unemployment rate, % older adults, % Black, % Hispanic, % uninsured, number of hospitals per 1,000 population, and number of beds per 1,000 population in 2012. Covariates are fixed at their pre-treatment level, corresponding to the baseline year, 2012.

Table 8: Effects of Residency Program Closures: Excluding year after 2019

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
ATT	-0.07154***	-0.05793**	-0.05635	-0.00931	0.15734	0.12407	0.29172	0.28267
	(0.02725)	(0.02754)	(0.17630)	(0.14228)	(0.12505)	(0.10970)	(0.20566)	(0.20682)
	34518	34503	34518	34503	34518	34503	34518	34503
Mean of Dependent Variable	10.979		2.384		2.339		2.526	
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
All outcome variables are per 1,000 population except for the outpatient visits, which are per population. Inpatient days are divided by 52 to convert from per week to per year. Inpatient cost is adjusted with 2020 CPI.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

Table 9: Effects of Residency Program Closures on Mortality Rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mortality Rate		Total Inpatient		Inpatient Days		Outpatient Visits	
ATT	-0.20970***	-0.17178***	-0.04829	-0.01708	0.18107*	0.14944*	0.20725	0.20970
	(0.05853)	(0.04509)	(0.15088)	(0.12401)	(0.09777)	(0.08996)	(0.17402)	(0.17440)
Observations	5346	5346	5346	5346	5346	5346	5346	5346
County Level Controls	No	Yes	No	Yes	No	Yes	No	Yes

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. ATT is the simple average of group-time average treatment effects, which is the average treatment effect for the group of counties that experience residency program closure at time g in period t.
All outcome variables are per 1,000 population except for the outpatient visits, which are per population. Inpatient days are divided by 52 to convert from per week to per year. Inpatient cost is adjusted with 2020 CPI.
County level controls include log of median income(adjusted with 2020 CPI), unemployment rate, % older adults, % black, % hispanic and % uninsured, number of hospitals per 1,000 population and number of beds per 1,000 population in year 2012. We fixed the covariates at the pre-treatment level which is our start year, 2012.

A Descriptive Statistics

Table A.1 reports the number of residency program closures by year. We present three increasingly broad definitions of programs: Family Medicine (FM) and Internal Medicine (IM) programs, a broader primary-care-related group, and all core residency programs in the sample. The table reports both the number of closed programs and the total number of observed programs in each category by year. In total, we identify 79 FM/IM closures out of 1,517 FM/IM program-year observations, 111 broader PCP closures out of 2,437 broader PCP program-year observations, and 341 closures out of 6,204 core program-year observations.

Table A.1: Number of Closed and Observed Residency Programs Each Year

	FM/IM Programs		Broader PCP Programs		All Core Programs	
Year	Closed	Total	Closed	Total	Closed	Total
2012	0	90	0	150	0	422
2013	5	80	10	152	26	387
2014	4	63	6	119	24	344
2015	5	90	6	149	18	423
2016	6	98	7	163	25	422
2017	4	124	9	207	36	495
2018	11	108	14	176	41	482
2019	6	156	12	244	42	589
2020	19	151	22	234	41	578
2021	8	126	12	226	32	551
2022	11	193	13	283	56	687
Total	79	1,279	111	2,103	341	5,380

Broader PCP programs include Family Medicine, Internal Medicine, Pediatrics, combined Internal Medicine/Pediatrics, Emergency Medicine, and Obstetrics and Gynecology programs.
Core programs refer to non-subspecialty residency programs. Total columns report the number of observed program-year observations in each category. Closure counts are reported by the year of closure.
Closure counts begin in 2013 because 2012 is our beginning of data.

Table A.2: Star-Rating Distribution and Mean Comparison: Closed-Program Hospitals vs. National Average

	Closed-program hospitals		National avg.	t-test
Star rating	Count (%)	Mean (SD)	Mean (SD)	(t-stat)
Year before closure ($t-1$)				
5 stars	2 (3%)			
4 stars	13 (18%)			
3 stars	39 (54%)	2.94 (0.82)	3.32 (0.96)	-3.83^{***}
2 stars	15 (21%)			
1 star	3 (4%)			
Missing	20 (22%)			
Closure year ($t=0$)				
5 stars	2 (3%)			
4 stars	19 (26%)			
3 stars	29 (40%)	2.96 (0.93)	3.32 (0.96)	-3.27^{***}
2 stars	18 (25%)			
1 star	4 (6%)			
Missing	20 (22%)			

Notes: Closed-program hospitals = facilities matched to an ACGME residency program that closed 2014-2022. Count (%) is the number at each CMS overall star rating (% of rated; Missing of all 92). Mean (SD) and t-tests use rated hospitals ($n = 72$ per panel). National avg. = all other CMS-rated hospitals, 2014–2022 ($N = 29{,}796$). t from a two-sample Welch test against the national mean. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

B Robustness Checks

Table B.1: Covariate Balance Before and After Propensity Score Matching

	Mean (SD)		
Variable	All counties	Treated counties	Matched control counties
Number of Observations	3139	54	432
Log median income	10.802 (0.235)	10.946 (0.202)	10.949 (0.310)
Unemployment rate	7.809 (2.798)	8.196 (2.131)	8.030 (2.772)
Black share	0.088 (0.144)	0.156 (0.151)	0.146 (0.176)
Hispanic share	0.087 (0.134)	0.164 (0.144)	0.152 (0.208)
Asian/Pacific Islander share	0.013 (0.028)	0.041 (0.028)	0.037 (0.054)
Female share	0.500 (0.023)	0.510 (0.011)	0.510 (0.012)
Age 65+ share	0.167 (0.043)	0.133 (0.029)	0.133 (0.029)
Uninsured share	0.142 (0.046)	0.133 (0.043)	0.133 (0.050)
Hospitals per population	0.057 (0.089)	0.019 (0.012)	0.018 (0.022)
Number of beds per population	3.164 (4.505)	3.977 (2.275)	3.402 (5.681)