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The effects of physician retirement on patient outcomes: Anticipation and disruption

Xuan ZHANG
Singapore Management University, xuanzhang@smu.edu.sg

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Xuan Zhang*

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Abstract

The physician retirement rate in the United States is increasing as the population ages. I use an event study model allowing for anticipation to evaluate the effects of primary care physician (PCP) retirement on elderly adults' health care utilization and quality of care. I find that, despite moderate anticipatory effects, PCP retirement results in an approximately $572 increase in total Medicare costs per beneficiary in the first 1.5 years post-retirement and an over 10% increase in detection of new chronic conditions. Heterogeneity analyses show that the increase in costs is disproportionately driven by the retirement of solo practitioners; Medicare beneficiaries with a retired PCP practicing in states with mandatory physician departure notice experience less disruption in care; and beneficiaries living in primary care health professional shortage areas experience greater disruption in care.

Keywords: Medicare; physician retirement; health care utilization; quality of care; anticipatory effect

JEL Codes: H51, I11, I12, J14, J26

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1 Introduction

The population in the United States (US) is aging. By 2030, all baby boomers will be over the age of 65, and the elderly population will account for one fifth of the total US population (US Census 2018). Seniors have an above-average need for health care services and higher medical costs. However, the physician population is also aging. In 2018, 43% of active physicians were already aged 55 or over and likely to retire within 10 years (Association of American Medical Colleges 2020).[1] The growing elderly population therefore faces an increased physician retirement rate and greater disruption in care precisely as their health care needs increase.

Given the expected high rate of physician retirement and the growing elderly population in the coming decades, a natural question to ask is how physician retirement affects patient outcomes. Unlike many other service professions, physicians, especially primary care practitioners (PCPs), accumulate abundant knowledge of patients' health conditions through repeated interactions over the years, and a continuous patient–physician relationship is considered to be valuable (Parchman and Burge 2004). In addition, PCPs tend to be the cornerstone of patients' coordinated care, and coordinated care can reduce medical costs (Agha et al. 2019). Therefore, the retirement of PCPs may be especially important. However, evidence on this is lacking (Lam et al. 2020). Therefore, in this paper, I explore how PCP retirement affects patients' health care costs and quality of care.

As a starting point, I note that physician retirement might be anticipated, since it usually involves careful planning (Silver et al. 2016), and some states require departing physicians to notify their patients no later than 30 days prior to their departure (Wall 2005). In addition, most patients see physicians in a group practice and thus may easily find a replacement. For these reasons, we might expect PCP retirement to have only mild effects on patients. However, this study shows that, despite anticipation, patient care is significantly disrupted at the moment of PCP retirement.

I use a 20% sample of Original (fee-for-service) Medicare claims from 2006 to 2015 and limit my sample to a panel of individuals aged 65 and over who entered the 20% sample in 2006 or 2007 and were included thereafter until their death. I restrict my sample to those who had full coverage of Medicare Part A & B and did not move during the sample period in order to avoid confounding

[1] Compared with other occupations in the service sector, this share is quite high (U.S. Bureau of Labor Statistics 2021).

factors that could also disrupt patient care.[2] I examine changes in primary care utilization as well as other forms of health care utilization, medical costs, and the quality of care due to PCP retirement. Original Medicare beneficiaries are not limited to a provider network and a referral is not needed to visit a specialist. Therefore, beneficiaries can freely choose any physician when seeking care, except for about 7% of physicians who do not accept Medicare (Boccuti et al. 2015).

My analysis is based on a flexible event study model that exploits variation arising from the timing of PCP retirement. I keep patients who had an initial PCP identified in 2006 or 2007. Patients whose initial PCP retired at age 60 or over (normal retirement) between 2010 and 2013 constitute the treatment group; patients who share similar characteristics but whose initial PCP of a similar age had not yet retired by 2013 serve as the matched control group. A conventional event study model makes two assumptions. The first is that the timing of an initial PCP's retirement is random conditional on patients' individual fixed effects, i.e., parallel trends in the baseline outcomes. The second is that PCP retirement is an unpredictable event, i.e., there is no anticipatory behavior. While the first assumption is plausible, and I find that there is no pre-trend in the baseline outcomes, the second is hardly satisfied.[3] Physician retirement generally involves careful planning, and thus PCPs may gradually reduce their working hours and convey information related to their retirement to patients as their planned retirement date approaches (Hedden et al. 2017). This action can affect patients' care-seeking behavior and patient outcomes even before a PCP retires. To account for this potential anticipatory behavior, I set the reference point as the ninth quarter before an initial PCP's retirement date to allow for a two-year lead period as the horizon for anticipation (Hendren 2017; Kuhn and Yu 2020). Therefore, the baseline is two years before PCP retirement. Anticipatory effects are captured by the two-year lead period, and any further disruption effects are reflected in the post-retirement estimates.

I find moderate anticipatory effects on primary care utilization, starting as early as two years prior to PCP retirement, and a moderate anticipatory effect on emergency care two quarters be-

[2] Non-movers are defined as Medicare beneficiaries whose residence remains in the same hospital service area (HSA), the geographic area where residents receive most of their health care services.

[3] In addition, I show that PCP retirement timing is uncorrelated with changes in the average difficulty of a PCP's patient pool, which rules out the possibility that a PCP's retirement is in response to the increased difficulty of her patients. Although I cannot fully rule out the possibility that there exists an unobserved factor, such as a PCP's declining health status, that can affect both her retirement timing and patient outcomes, given the limited ex-ante impact on other forms of care and little impact on the quality of care before PCP retirement, such bias is likely to be minimal.

fore PCP retirement; however, I find no anticipatory effects on other forms of care. The major effects take place immediately after PCPs retire. Primary care utilization declines by about 8.8% permanently and results in a persisting 7.9% increase in cardiology care, the most representative specialty care in the elderly population. By contrast, the effects of PCP retirement on emergency care, medical test use, and inpatient care are mainly short-term, lasting for 1.5 years only. In these six quarters, emergency room (ER) costs increase by 6.3%, diagnostic and imaging tests increase by 2.5% and 3.7%, respectively, and inpatient care costs increase by 4.0%. In the meantime, overall outpatient care costs increase by 3.2%. As a result, total Medicare costs increase by $95.27 (3.9%) per patient per quarter in the first 1.5 years. Therefore, a PCP retirement results in a $571.62 ($95.27*6) increase in per capita Medicare spending among Original Medicare beneficiaries. Given that a PCP on average has 20 dependent patients in the 20% Original Medicare sample, one PCP's retirement costs Medicare about $57,200 for the Original Medicare population.[4]

As medical costs increase due to PCP retirement, a follow-up question is whether quality of care changes. I find no effect on individual mortality and little impact on potentially avoidable hospitalizations due to acute ambulatory care sensitive conditions (ACSCs). However, I find an 11.9% increase in the detection of more than 10 chronic diseases in the second post-retirement quarter, and the average increase in detection in the first 1.5 years after PCP retirement is 7.9%. The early detection of diseases such as Alzheimer's disease and related disorders, depression, and osteoporosis is beneficial for patients' long-term well-being (Leifer 2003; Tucci 2006; Park and Unützer 2011). A back-of-envelope calculation indicates that federal savings from the early diagnosis of Alzheimer's disease and related dementia offset at least 7% of the increase in Medicare costs due to PCP retirement. In addition, patients who find a replacement PCP are able to switch to a new PCP of slightly higher quality in diabetes management (better adherence to preventive tests for diabetics) and flu vaccination.

After investigating the average intention-to-treat (ITT) effects, I investigate heterogeneous effects by (1) whether a retired PCP is a solo practitioner or part of a group practice, (2) whether a retired PCP practices in a state that requires physician departure notice to patients, and (3) whether Medicare beneficiaries live in a primary care health professional shortage area (HPSA). For (1), I

[4]Dependent patients are patients who chose a PCP as their initial accountable PCP in 2006 and/or 2007. Twenty is the average number of dependent patients based on my calculation from the 20% sample in 2007 and 2008. Medicare costs are payments from Medicare.

find that patients with a retired solo PCP experience a greater disruption in care and a much larger increase in Medicare spending. Although they experience a bigger improvement in their replacement PCP's quality, the improvement in the quality of care is relatively small, except for a 44.3% higher likelihood of new chronic disease detection. For (2), mandatory physician departure notice is not only effective at mitigating the disruption in care and curtailing the increase in costs, but it also contains the increase in hospitalization rates due to acute ACSCs. For (3), patients in primary care HPSAs face a larger increase in medical costs, but there is essentially no difference in the quality of care received from their partial or non-HPSA counterparts after PCP retirement.

With the expected rise in the number of PCPs retiring due to population aging, we can foresee a sizeable increase in total Medicare costs in the coming years. A back-of-envelope calculation suggests that Original Medicare would face a $4.3 billion increase in spending from 2018 to 2028 due to normal PCP retirements compared to a scenario in which PCPs delay their retirement. Part of the increase in costs can be paid back through long-term savings, such as through the early detection of Alzheimer's disease and related dementia, depression, and osteoporosis. Some of the disruption costs can be avoided by implementing effective policies, such as state-level mandates on physician departure notice and increasing the supply of PCPs in physician shortage areas. In addition, solo practitioners may especially need to facilitate a smooth transition for patients.

This study contributes to the literature examining the role of primary care in health care systems. Previous studies have linked greater use of primary care and continuity of care with lower medical costs and higher health care quality (Weiss and Blustein 1996; Friedberg et al. 2010; Phillips and Bazemore 2010; Nyweide et al. 2013; Romano et al. 2015; Schneider and Squires 2017). However, these conclusions have been based on associations instead of causal inference. Pereira et al. (2003) and Reddy et al. (2015) find no impact of PCP turnover on the quality of preventive care in specific group practice settings. In addition, disruption in primary care has trade-offs. A seldom noticed potential benefit of discontinuity of care is that it may help patients get a fresh eye to detect some overlooked chronic diseases.

Several concurrent studies have examined the causal effects of practice closure on patient outcomes in Denmark and Switzerland, PCPs' practice styles on patients' health care utilization, and the value of the PCP–patient relationship by exploiting PCP exits and relocation using Medicare claim data (Kwok 2019; Fadlon and Van Parys 2020; Sabety 2020; Bischof and Kaiser 2021; Simonsen et al. 2021). I focus on PCP retirement, as it potentially involves stronger anticipatory effects than other types of physician departure due to the noticeable sign of physician aging. There is also a potentially stronger post-departure disruption effect given the permanent cessation of practice and the fact that patients unable to follow a PCP like in the physician migration scenario. Moreover, population aging has created pressure on the health care system from both the demand side and the supply side. Therefore, it is important to quantify the costs of PCP retirement due to physician aging. In addition, I consider the trade-off between health care costs and quality of care due to disruption in primary care, showing that some short-term costs can bring long-term benefits via improved care quality, whereas some costs can be avoided. Finally, I conduct three policy-relevant heterogeneity analyses, which shed light on the mechanism behind the effects of PCP retirement on patients and generate practical policy implications.

The rest of the paper proceeds as follows. Section 2 describes the data, sample, variable definitions, and summary statistics. Section 3 illustrates the empirical strategy. Section 4 shows the effects of PCP retirement on patient health care utilization and medical costs, and Section 5 analyzes the effects on quality of care. Section 6 investigates the heterogeneous effects, and Section 7 concludes.

2 Data, Sample, and Summary Statistics

2.1 Data

This paper uses Medicare beneficiary summary files and 20% Original Medicare claim files on part of Medicare Part A (MedPAR, hospital inpatient and skilled nursing facility), Part B (hospital outpatient and carrier), and Part D (prescription drug) for the period 2006–2015.[5] The data contain detailed information on patients' doctor/hospital visits, costs, diagnoses, procedures, and death date, but are limited in terms of the patient demographic characteristics included. Therefore, I link the Medicare claim data to the 2010 Census through the ZIP code to ZIP Code Tabulation Area (ZCTA) crosswalk to obtain patients' neighborhood characteristics. To identify non-movers in the sample, patients' residence ZIP codes are grouped into HSAs and hospital referral regions (HRRs)

[5]The beneficiary summary file includes patients enrolled in Medicare Advantage, but claim files in general do not. Therefore, I only conduct analyses based on the Original Medicare beneficiaries.

following the Dartmouth Atlas.[6]

Two physician-level data sources are used: the 2008–2015 Medicare Data on Provider Practice and Specialty (MD-PPAS) and the 2007 Medicare Physician Identification and Eligibility Record (MPIER). From the 2008–2015 MD-PPAS, I obtain each physician's birth date and the number of unique patients the physician saw each year. From the 2007 MPIER, I identify each physician's group/solo practice affiliation, medical school attended, graduation year, and whether she is board-certified.[7] However, as the MPIER data end by quarter 2 of 2007, new physicians entering the Medicare system afterwards are not included.

In addition, to study the heterogeneous effects, I use another two data sources. First, I collect data from state medical boards or relevant legislation regarding whether a state requires physicians to notify patients before their departure. Second, I use the Area Health Resource Files (AHRF) to identify if a county is fully, partially, or not designated as a primary care HPSA in 2006–2015.

2.2 PCP Retirement

This study uses a broad concept of PCP, including not only physicians specialized in general practice, family medicine, internal medicine, and geriatrics, but also non-physicians such as nurse practitioners, physician assistants, and clinical nurse specialists, as long as they assume primary care responsibility for patients (CMS 2017*a*). In my sample, only around 6% of patients choose a non-physician as their main source of primary care. I construct work trajectory for each PCP using her national provider identifier (NPI), service date, and service ZIP code from the Medicare carrier claims.[8]

A PCP is defined as retired if the last time she filed a Medicare claim was by December 2013. Therefore, a PCP's retirement date is the last date I observe she filed a claim.[9] Although in principle

[6]HSAs are local health care markets for hospital care. HRRs represent regional health care markets for tertiary medical care. There are 3,436 HSAs and 306 HRRs in the US. The data can be downloaded from: http://www.dartmouthatlas.org/tools/downloads.aspx

[7]Since 0.26% of PCPs' birth dates are missing in the MD-PPAS, I replace their age with 26 + (given year-graduation year), assuming they graduated at 26, the average medical school graduation age in the US.

[8] There was a reform of provider ID in early 2007, which converted unique provider identification numbers (UPINs) to NPIs. I use the NBER UPIN to NPI crosswalk to covert UPINs to NPIs. For those UPINs with no information from the NBER crosswalk, I derive the correspondence from the Medicare data I have.

[9]A PCP exit can be driven by other reasons, such as opting out of Medicare, cessation of medical license, and death. PCP death is less likely to affect my estimates, but if patients still visit a PCP who opts out of Medicare, then Medicare claims miss this information and thus I may overestimate the disruption. Similarly, if a PCP "retires" because

PCPs can retire at any age they wish, early retirements are often associated with non-random negative shocks to physicians and are thus endogenous (Dewa et al. 2014; Silver et al. 2016).[10] Therefore, in my main analysis, I only keep convincingly normal retirement events, namely PCPs retiring at age 60 or over.

Figure 1 depicts the distribution of PCP retirement ages and distribution of PCP retirement dates. As expected, the peak retirement age is 65, but retirement ages vary widely from the 30s to 90s; PCP retirement dates are cyclical throughout the year, with peaks in December. In addition, the retirement rate increases steadily year by year. There is no noticeable impact from the 2008 economic crisis, which alleviates the threat of PCPs selecting into retirement due to the crisis. Since I account for potential anticipatory behavior two years before a PCP retires, I focus on PCP retirement dates from 2010 to 2013 in order to have a long enough pre-retirement period.

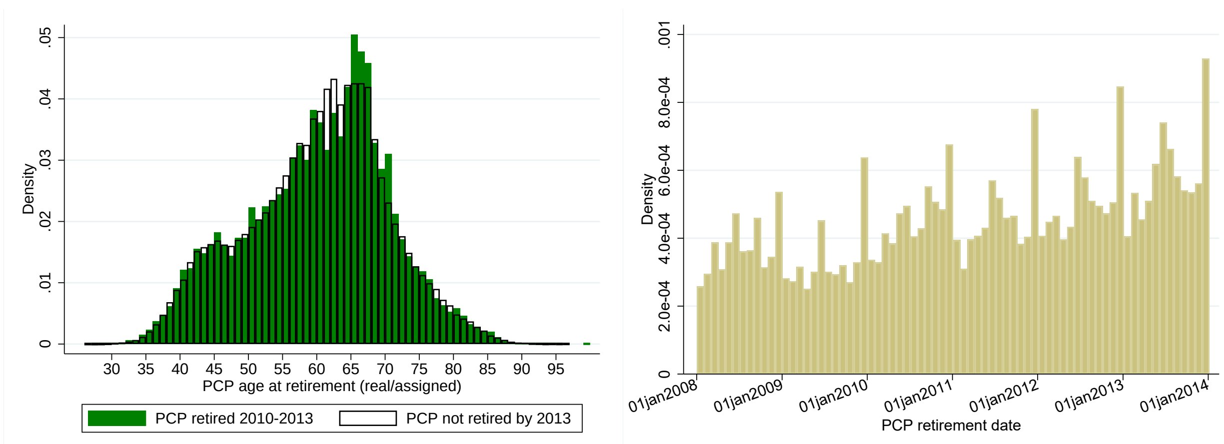


Figure 1: Distribution of PCP Retirement Ages and Retirement Dates

Note: In the left figure, for the matched control group, a PCP's "retirement age" is calculated for her randomly assigned "retirement date" between 2010 and 2013, following the distribution of retirement dates in the treatment group. In the right figure, each bin represents a month.

of malpractice, it may also bias my estimates. However, a back-of-envelope calculation shows that PCPs' Medicare opt-outs account for about 8% of the exits (Buczko 2004; Beck 2013; Shartzer et al. 2013), and medical license cessations account for only 3% of the exits (Jena et al. 2011; Federation of State Medical Boards 2018). Overall, these factors account for 11% of all exits, so their influence on my estimates is small.

[10] Figure A1 (see Appendix A) provides additional evidence that early retirement is problematic (especially when physicians are aged 50–59). The downward pre-trend during the baseline period suggests an abnormal reduction in primary care utilization, consistent with the signs of physician burnout, one of the commonly mentioned reasons for early retirement.

2.3 Patient Sample

My overall patient sample is a panel of the senior Original Medicare beneficiaries who were included in the 20% random Medicare sample from 2006 or 2007 for at least one complete year and were included until 2015 or until their death. I apply two restrictions to the sample to avoid disruptions in primary care due to other confounding factors. First, I keep patients with full coverage of Medicare Part A and Part B, because patients with partial coverage are likely to use only those health care services that are covered, and I lose track of patients when they opt out of Original Medicare and switch to Medicare Advantage (Part C). Second, I limit my patient sample to non-movers who lived in the same HSA for the entire sample period in order to eliminate disruption in care due to patients moving and to avoid geographic factors that directly influence patients' health care utilization and costs (Song et al. 2010; Finkelstein et al. 2016; Molitor 2018).

In addition, since the main source of variation comes from PCP behavior, a necessary condition for being included in my analysis is that patients must have at least one accountable PCP over the sample period. A patient's accountable PCP in a year is defined as the PCP who accounts for the largest proportion of the patient's primary care services in that year (CMS 2017*a*). Although many restrictive insurance types, such as HMO, request patients to stick with only one PCP, about half of the Original Medicare patients visit more than one PCP annually, mainly due to there being no limit on provider network by Original Medicare. Nevertheless, patients generally have an easily identifiable accountable PCP in each year. Columns (3)–(5) of Table A1 show the sample size and sample characteristics after each restriction is applied. In general, adding these restrictions to the sample does not change the average characteristics of patients.

Among patients with at least one accountable PCP during the sample period, I focus on patients who had an initial accountable PCP in 2006 or 2007 and assign them to the treatment or control group based on their initial PCP's retirement status as of 2013. My treatment group consists of patients whose initial PCP retired between 2010 and 2013 (inclusive of 2010 and 2013), and my control group consists of patients whose initial PCP had not yet retired by 2013.[11] I adopt this conservative but clean way of constructing the sample for two reasons. First, this design eliminates the potential bias due to selection into treatment. For example, patients who start to see an about-to-retire PCP, who stay with this PCP, or who switch to another PCP long before this PCP's retirement

[11]The implied counterfactual here is what would happen if PCPs delayed their retirement.

may have different unobserved time-varying characteristics that could directly affect their health care utilization and/or health outcomes. Second, physicians' retirement decisions are hardly made suddenly, since retirement planning is common among physicians (Silver et al. 2016; Hedden et al. 2017). Therefore, a clean baseline should be relatively far away from the retirement, as both physicians' and patients' behavior might change during the retirement planning period, i.e., possible anticipatory behavior. By tracking patients from early on, I have a clean baseline period.

For my main analysis, I focus on PCPs' normal retirement and construct a matched control group of patients who have similar characteristics as my treatment group. For each patient in the treatment group, I randomly draw a patient in the control group who shares the same gender, race, five-year age bin in 2006 (65-69, 70-74, 75-79, 80-84, 85-89, 90+), and residence (HSA), and whose not-yet-retired PCP's age falls into the same five-year age bin in 2006 (50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80+) and has the same medical degree (MD/DO or not) as the treatment group patient's retired PCP.[12]

2.4 Outcome Variable Definitions

I. Health care utilization and Medicare cost

I start by examining the change in **primary care** utilization, the direct impact of PCP retirement. Then, I look at the effects of PCP retirement on other related forms of care: **specialty care, emergency care, prescription drug use, medical tests, and inpatient care**. For each form of care, I consider changes in the following dimensions: average costs, whether a patient uses the care (extensive margin), and costs conditional on use (intensive margin). To avoid influence from inflation, all costs are measured in 2010 USD.

For primary care, although disruptions are brought about by accountable PCPs' retirements, I look at the change in overall primary care utilization, since primary care costs from non-accountable PCPs account for about 13% of all primary care costs. Moreover, restricting visits to accountable PCPs only may overestimate the disruption.[13] For specialty care, I use cardiology as a representative example, since cardiologists are the type of specialist that Medicare patients visit most fre-

[12] I also include patients who entered the sample in 2007 and were 64 in 2006 in the matching process.

[13] When patients temporarily switch to a new PCP and then permanently switch to another PCP, this first-observed new PCP might be classified as a non-accountable PCP. If I only consider patient visits to accountable PCPs, visits to this first new PCP are overlooked, and the overall disruption is overestimated.

quently for consultation purposes.[14] For both primary care and specialty care, I only consider visits in outpatient settings to avoid changes in PCP and specialist visits that are triggered by changes in hospital admissions. For inpatient care, in addition to total hospitalizations, I also look separately at hospitalizations by physician referral and hospitalizations through ER.

In addition, I examine whether disruption in care leads to more diagnostic and imaging tests. On the one hand, difficulty in accessing previous medical records is one of the main reasons for physicians to order medical tests (Lyu et al. 2017), and medical tests incur huge costs (Kaiser Family Foundation 2017). On the other hand, by taking a fresh look, new physicians may notice unusual patterns in patients and thus order medical tests for a more careful examination.

For the above-mentioned care utilization, except for ER charges and medical tests, I consider the Medicare costs for each of them, i.e., Medicare payment.[15] In addition, I also calculate **total (Original) Medicare costs** for each patient by adding up Medicare payments from MedPAR (for inpatient and skilled nursing facility), Part B (for hospital outpatient and physician services), and Part D (for prescription drugs) claims.

II. Quality of health care

I evaluate the quality of care by examining patients' health outcomes, potentially avoidable hospitalizations, detection of new diseases, and accountable PCP quality. First, the specific patient health outcome I look at is individual mortality, which is an ultimate measure of one's health status. Second, I analyze hospitalizations due to ACSCs, since high-quality primary care (and other clinical services) can greatly limit wasteful inpatient admissions due to these conditions (Agency for Healthcare Research and Quality 2001; Gao et al. 2014). There are two types of ACSCs: acute and chronic. Acute ACSCs include bacterial pneumonia, urinary tract infections, and dehydration. Chronic ACSCs include chronic obstructive pulmonary disease (COPD), diabetes, and congestive heart failure. All patients are considered in terms of admissions due to acute ACSCs, but only patients with the relevant existing chronic condition are considered when examining chronic ACSC admissions, i.e., I only keep patients for analysis from calendar year $t+1$ after they were first diag-

[14]In my data, visits to cardiologists account for over 10% of all types of specialist visits, ranked third. The top two are clinical laboratory and diagnostic radiologists, but most visits to these two types of specialists are due to other physicians' referrals and are less likely to reflect patients' active health care-seeking behavior.

[15]For ER costs, I consider the charges using the revenue center codes for the outpatient files and ER charges from the MedPAR instead of the Medicare payment. Appendix B **ER utilization** provides more details.

nosed with a chronic ACSC in year t.[16] Third, I investigate changes in the detection of new chronic diseases. For chronic conditions, it is unlikely that patients will suddenly develop a condition right after PCP retirement. Therefore, changes in diagnoses tend to reflect (early) detection rather than the deterioration of patients' health status due to PCP retirement. Finally, I consider the quality of PCPs. I follow the estimation of teacher value-added in Chetty et al. (2014) to construct a quality measure of PCPs based on their adherence (contribution) to recommended preventive procedures: annual hemoglobin A1c (HbA1c) and lipid tests for diabetics and flu vaccine for all senior patients. The details of the construction of the PCP quality measures are given in Appendix B.

2.5 Summary Statistics

Table 1 shows the characteristics of patients and their initial PCPs in the treatment and control groups. Patients' individual characteristics are measured in their first observed year, i.e., 2006 or 2007. Column (1) describes the characteristics of the potential treatment group, which includes not only patients with normal PCP retirements, but also patients with early PCP retirements. Column (2) limits the sample to the treatment group, whose initial PCP retired at age 60 or over, and column (3) includes the control group, whose initial PCP had not retired by 2013. The differences between the treatment and control groups are small in terms of most patient characteristics. However, in terms of their initial PCP's characteristics, as expected, retired PCPs are older, have fewer patients, are more likely to be solo practitioners, and are of lower quality. When matching patients' demographic characteristics and PCPs' age group and degree (columns [4] and [5]), patient characteristics become almost identical: the gap between their initial PCP's characteristics shrinks, although most of the differences are still statistically significant due to the big sample size.[17] Comparing the matched treatment and control groups, their PCPs have similar ages, similar solo and group practice proportions, similar requirements for departure notice, and similar adherence to the lipid test. The matched treatment group's PCPs have slightly better adherence to the HbA1c test,

[16] In addition, since the Centers for Medicare & Medicaid Services (CMS) replaced ICD-9 codes with ICD-10 codes in October 2015 and I use ICD-9 diagnosis codes to identify ACSCs, only data up to September 30, 2015 are kept for analyses on avoidable hospitalizations.

[17] The only difference that cannot be eliminated between the matched treatment and control groups is the number of unique patients in 2008. As long as the number of patients does not affect the trends of patient outcome changes, the gap is not an issue. Given the parallel trends between the treatment and control groups in the baseline period, this assumption holds. In addition, Alkalay et al. (2018) show that PCP workload does not affect patients' health care utilization, except that high workload reduces referrals to lab tests.

but slightly worse adherence to flu vaccination.[18]

My main analysis is based on the matched treatment and control groups in columns (4) and (5). However, it should be noted that the matched sample is slightly healthier and richer than the unmatched sample, as individuals in the matched sample are less likely to be dually eligible or disabled, have fewer chronic conditions, and have lower risk scores.[19] In addition, the matched sample is less likely to rely on a non-MD/DO accountable PCP, and patients in the matched treatment group have an initial PCP of higher quality than their unmatched counterparts. Therefore, my main estimates based on this matched sample might be in the lower bound of PCP retirement effects due to these better traits of both patients and PCPs.

As robustness checks, I conduct the analyses on two alternative samples. First, instead of having a control group whose PCP did not retire by 2013, I use an alternative control group whose PCP did not retire by quarter 4 of 2015 (the last quarter in my sample) and construct the matched treatment and control groups accordingly (Deshpande and Li 2019). Compared to my main control group, this control group should have almost no potential anticipatory behavior, and thus using this alternative matched sample (matched sample 2) is likely to generate larger estimates. Second, I use the whole treatment group only (column [2]) without constructing a control group to see if the results still hold. Since the whole treatment group has worse characteristics than the matched sample, I also expect the estimates to be larger.

In addition, I also consider all PCP retirements (including early retirements) by comparing column (1) and a 10% random sample of column (3). The analysis is shown in Appendix C.

3 Empirical Strategy

I use the variation in PCP retirement timing to estimate the effects of PCP retirement on patient outcomes. One key identification assumption is that PCP retirement timing is random conditional on patient fixed effects, i.e., PCP retirement timing is not caused by changes in patient characteristics, and there are no unobserved concurrent factors that affect both the retirement timing and

[18]Table A2 shows the standard deviations (SDs) of the PCP value-added measures, as the change in PCP quality is measured relative to the SD of each value-added. In addition, Table A3 shows positive correlations between PCP value-added and other quality measures.

[19]Dual eligibility means that a beneficiary is eligible for both Medicare and Medicaid. In general, only low-income seniors are eligible for Medicaid.

Table 1: Summary Statistics of Patients

	General analysis sample			Matched analysis sample		
	(1) Potential treatment group (PCP retired 2010–2013)	(2) Treatment group (PCP retired 60+)	(3) Control group (PCP did not retire by 2013)	(4) Matched treatment group	(5) Matched control group	(6) Difference (p-value)
Individual characteristics						
Age in 2006	76.10	76.34	76.03	76.19	76.20	0.79
Share male	0.41	0.42	0.40	0.42	0.42	1.00
Share white	0.89	0.90	0.90	0.93	0.93	1.00
Share black	0.07	0.06	0.06	0.05	0.05	1.00
Share dually eligible (FY)	0.12	0.11	0.11	0.08	0.08	1.00
Share disabled (FY)	0.08	0.08	0.08	0.07	0.07	0.66
No. of chronic conditions (FY)	3.82	3.72	3.83	3.71	3.76	0.00
HCC score (FY)	1.06	1.02	1.03	1.01	1.02	0.06
Share of non-MD PCPs	0.08	0.04	0.05	0.03	0.03	1.00
Number of quarters	30.25	30.03	30.25	30.27	30.27	0.96
Neighborhood characteristics						
Mean household income	70,583	71,129	70,865	71,869	71,844	0.83
Median household income	55,991	56,493	56,434	57,119	57,068	0.56
Population	24,478	24,615	24,859	24,825	24,928	0.11
Share rural	0.25	0.25	0.24	0.24	0.24	0.78
Share white	0.72	0.72	0.72	0.73	0.73	0.00
Share elderly	0.16	0.16	0.16	0.16	0.15	0.00
Share house vacant	0.11	0.11	0.11	0.11	0.11	0.01
Share primary care HPSA	0.40	0.40	0.39	0.39	0.40	0.00
Initial PCP characteristics						
PCP age in 2011	60.22	67.93	53.87	66.70	66.36	0.00
No. of uniq. patients (2008)	359	352	426	361	423	0.00
Share solo practice (pure)	0.17	0.20	0.14	0.20	0.21	0.00
Share group practice (pure)	0.55	0.53	0.58	0.53	0.51	0.00
Share mandatory departure notice	0.60	0.60	0.62	0.60	0.59	0.00
PCP adherence to (value-added):						
HbA1c test	-0.0055	-0.0079	-0.0003	-0.0067	-0.0076	0.00
Lipid test	-0.0151	-0.0180	-0.0019	-0.0150	-0.0148	0.65
Flu vaccination	-0.0047	-0.0028	0.0026	-0.0020	-0.0009	0.00
N	293,665	169,270	2,468,502	143,271	143,271	

Notes: (FY) indicates a patient's first-observed year. The Hierarchical Condition Category (HCC) risk score is calculated based on patients' demographic characteristics and diagnoses. Number of quarters are the number of quarterly observations in regressions. Neighborhood characteristics are measured in 2010 at the ZIP code level, based on patients' first observed ZIP code in 2006/2007, except for county-level HPSA designation. PCPs' number of unique patients comes from the MD-PPAS, available since 2008. It includes all Medicare patients a PCP saw in 2008, not only the 20% random sample and not necessarily the patients who relied on this PCP as an accountable PCP. (pure) indicates that a PCP is only affiliated with solo or group practice(s); the rest of PCPs are affiliated with both types of practices or have missing information on active affiliations. PCP's adherence to preventive procedures is measured using the teacher value-added method in Chetty et al. (2014). Difference (p-value) shows the t-test results for the mean difference between the matched treatment and control groups. N represents the number of patients in each column.

patient outcomes. This is plausible, since physicians usually plan carefully for retirement by considering their own financial needs, physical condition, and mental health status (Silver et al. 2016). Therefore, PCP retirement is very unlikely to be driven by unobserved time-varying patient characteristics. Table A4 demonstrates that PCP retirement timing is not correlated with changes in the difficulty of a PCP's patient pool (measured by the average risk score and cost of patients) prior to retirement.

Another assumption for a conventional event study is that there is no anticipatory behavior. This assumption probably does not hold for PCP retirement events, as PCP retirement often involves considerable planning, and thus there may be some signs of the PCP's retirement prior to the planned retirement date. For example, physicians may start to reduce their workload and notify/transfer patients when it is around two years or closer to their planned retirement date (Hedden et al. 2017). Consequently, more alert patients may respond earlier by switching PCPs before their PCP's retirement date.[20] To account for this potential anticipatory effect, I set the reference time as two years prior to a PCP's retirement date. Therefore, the whole treatment period consists of a two-year lead period and the post-retirement period.

As illustrated in Section 2.3, my main analysis sample consists of patients who had an initial PCP in 2006/2007 (mostly in 2006) and their initial PCP retired between 2010 and 2013 or had not yet retired by 2013. Therefore, for the majority of patients, I observe their care-seeking behavior and patient outcomes for at least four years leading up to their initial PCP's retirement. The underlying assumption is that going back four years, patients' choice of a PCP is not correlated with the PCP retirement event taking place in the future. This sample construction, as explained in Section 2.3, avoids the potential bias due to selection into treatment and provides a clean baseline before the anticipatory behavior begins. Using this study design, I estimate ITT effects, because patients may have already voluntarily switched PCPs even before entering the lead period. In fact, only about 60% of the treatment group maintain their initial PCP when entering the lead period and thus get treated by the retirement of their initial PCP.[21]

My analysis is based on a flexible event study model, as shown in equation (1) (Jacobson et al.

[20] When comparing patient characteristics of those who switch early vs. those who switch after their PCP retires, I find that those who switch early are younger, richer, and healthier.

[21] Given that $treated = 1(PCP\ retired\ \&\ patients\ stayed\ with\ this\ PCP\ when\ entering\ the\ lead\ period)$, and $treat = 1(PCP\ retired)$, the first stage estimate is 0.6.

1993; Bailey and Goodman-Bacon 2015; Borusyak and Jaravel 2017):

$$y_{it}^{(k)} = \underbrace{\sum_{k=-28}^{k=-10} \eta_k D_i 1(t - t_i^* = k)}_{\text{Baseline}} + \underbrace{\sum_{k=-8}^{k=-1} \theta_k D_i 1(t - t_i^* = k)}_{\text{Anticipatory effect}} + \underbrace{\sum_{k=0}^{k=19} \beta_k D_i 1(t - t_i^* = k)}_{\text{Post-retirement effect}} + \gamma \cdot X_{it} + \alpha_i + \sigma_t + \varepsilon_{it} \quad (1)$$

Here, $y_{it}^{(k)}$ represents patient i's health care utilization, medical costs, and quality of care in each quarter t, as defined in Section 2.4. On the right-hand side, D_i is the treatment group indicator. Including the control group can better pin down the time fixed effects. t_i^* is the PCP retirement date (by quarter) for patient i. $1(t - t_i^* = k)$ takes a value of 1 when a quarter is -28,...0,...19 relative to the PCP retirement timing t_i^*.[22] $t - t_i^* >= 19$ is captured by $1(t - t_i^* >= 19)$, and $t - t_i^* <= -28$ is captured by $1(t - t_i^* <= -28)$. The relative quarter right before the two-year lead period of PCP retirement ($k = -9$) is set as the reference. X_{it} includes time-varying individual characteristics, such as five-year age bin, disability, and dual eligibility status.[23] α_i captures patient fixed effects, and σ_t captures calendar quarter fixed effects. Standard errors are clustered at the initial accountable PCP level.

The whole time period is divided into three sub-periods relative to the retirement timing t_i^*: the baseline period (relative quarters earlier than -9), the lead period (relative quarters between -8 and -1), and the post-retirement period (relative quarters from 0 onward). The point estimates, $\{\eta_k\}$, describe the evolution of outcome $y_{it}^{(k)}$ net of the changes in the control group in the baseline period after adjusting for model covariates. These estimates allow for a direct evaluation of the assumption that a PCP retirement event is unrelated to baseline changes in $y_{it}^{(k)}$. Both θ_k and β_k are coefficients of interest, estimating the ITT effects of PCP retirement on the treatment group, where θ_k reflects the anticipatory behavior, while β_k captures the dynamic treatment effects after a PCP retires.

In addition, I summarize the estimated effects by sub-period with a difference-in-differences

[22] The day that a PCP retired is the first day in relative quarter $k = 0$. However, patient i's visit to this initial accountable PCP on the PCP's retirement day is coded as taking place in relative quarter $k = -1$. Her visit to other PCPs and other health care utilization on that day, if any, is still treated as occurring in relative quarter $k = 0$.

[23] The estimation does not include control variables such as the number of chronic conditions ever diagnosed and the HCC risk score in the last year, because these measures are correlated with a replacement physician's judgment of new diagnoses, and they may absorb the changes in patient outcomes.

(DID) model in equation (2):

$$y_{it}^{(k)} = \theta \cdot D_i * 1(t_i^* - 8 \leq k \leq t_i^* - 1) + \beta_1 \cdot D_i * 1(t_i^* \leq k \leq t_i^* + 5) + \beta_2 \cdot D_i * 1(k \geq t_i^* + 6) + \gamma \cdot X_{it} + \alpha_i + \sigma_t + \varepsilon_{it} \tag{2}$$

In the DID specification, the individual quarter dummies are replaced by three indicators of the three treatment periods: the two-year lead period $1(t_i^* - 8 \leq k \leq t_i^* - 1)$, the post-retirement sub-period 1 $1(t_i^* \leq k \leq t_i^* + 5)$, and the post-retirement sub-period 2 $1(k \geq t_i^* + 6)$. Therefore, the DID model estimates the average quarterly effect in each time period. The other variables are the same as in the event study model, and standard errors are clustered at the initial accountable PCP level. Using a DID model has two advantages. First, by lumping together multiple relative quarters with similar dynamic effects, the estimates are tighter. Second, it is simpler to summarize the results with three key coefficients rather than with 47 coefficients in the event study model.

Individual fixed effects are included in analyzing the effects on all patient outcomes except for individual mortality. Instead, treatment group indicator D_i is used to control for the potential level difference in mortality between the treatment and control groups. In addition, when assessing the effect on individual mortality, in addition to the linear probability model, I use a Cox Proportional Hazard model to analyze how PCP retirement affects the hazard of death:

$$h(t) = h_0(t) exp(\theta \cdot D_i * 1(t_i^* - 8 \leq k \leq t_i^* - 1) + \beta_1 \cdot D_i * 1(t_i^* \leq k \leq t_i^* + 5) + \beta_2 \cdot D_i * 1(k \geq t_i^* + 6) + \gamma \cdot X_{it} + D_i + \sigma_t) \tag{3}$$

4 Results: Effects on Health Care Utilization and Costs

This section shows the effect of PCP retirement on patients' health care utilization and medical costs. Graphical evidence from the event studies in equation (1) and regression outputs from the DID models in equation (2) are presented.

4.1 Primary Care Utilization

As shown in Figure 2 and Table 2, primary care utilization remains almost constant during the baseline period. However, the probability of having any PCP visit (the extensive margin) starts to decline two years before PCP retirement. During the relative quarters -8 to -2, primary care utilization reduces by about 1 percentage point (1.6%), which demonstrates the existence of an anticipatory effect.[24] However, despite this anticipation, the probability of visiting a PCP further declines sharply by about 3.74 percentage points (5.9%) in the first four years after PCP retirement. Although this probability increases slightly at the end of the fourth year, it is still about 3 percentage points (4.7%) lower than it was during the baseline period. As for the intensive margin, the changes are small. Per capita conditional primary care costs increase by about \$6 (4.4%) per quarter only in the first half a year after PCP retirement and remain similar at other times. With the significant changes at the extensive margin and little change at the intensive margin, the average quarterly per capita primary care costs decrease slightly by about \$1 (1.2%) in relative quarters -8 to -2 and decrease by \$4.43 (5.1%) in the first 1.5 years and by \$7.64 (8.8%) in the rest of the post-period.

4.2 Other Health Care Utilization

I. Specialty care

Figure 3 reveals that there is no anticipatory behavior related to cardiology care, but patients greatly increase their cardiology care-seeking right after their PCP retires. In the first post-retirement year, the average per capita cardiology care spending increases by nearly \$4 per quarter, a 10% increase from the baseline. Although the spending goes down after the first year, patients still spend around \$3 more per quarter on cardiology care than they did before. Moreover, the substitution of primary care with specialty care persists for at least five years. Overall, as shown in Table 3, PCP retirement results in a permanent \$3.18 (7.9%) increase in cardiology care costs. By comparing estimated post-retirement effects on primary care and cardiology care, I find that a \$1 reduction in primary care utilization is roughly substituted by a \$0.80 (\$3.55/\$4.43) increase in cardiology care in the first 1.5 years and a \$0.42 (\$3.18/\$7.64) increase in cardiology care for the rest of the post-period.

The increase in specialty care may be driven by two potential channels: (1) patients relying on a specialist as their primary care source and (2) patients increasing specialist visits in addition

[24]Primary care utilization surges mechanically in relative quarter -1 because a patient's visit to the retiring accountable PCP on her retirement day is included in quarter -1. Therefore, the anticipatory effect for primary care utilization is more accurate between relative quarters -8 and -2 (inclusive).

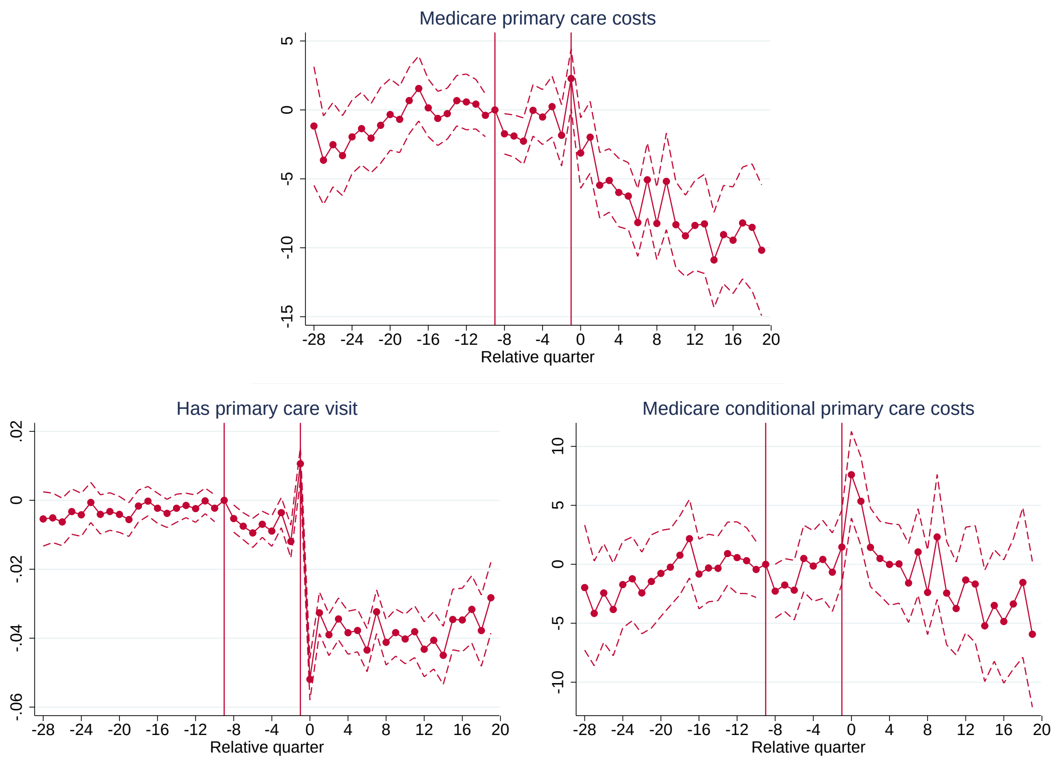


Figure 2: Effect of PCP Retirement on Primary Care Utilization

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1. PCP visits and costs include not only visits to a patient's accountable PCP but also visits to any other PCP. Average primary care costs consist of per capita Medicare spending on primary care per quarter. Having a PCP visit (extensive margin) is a dummy variable, indicating whether a patient has at least one PCP visit in a relative quarter. Conditional costs (intensive margin) are calculated only if a patient has a PCP visit in a quarter. All costs are measured in 2010 USD.

Table 2: Effect of PCP Retirement on Primary Care Utilization

	Average costs	**Has PCP visit**	**Conditional costs**
PCP retired*Lead-period	-0.63	-0.0034*	-0.47
	(0.67)	(0.0015)	(0.93)
PCP retired*Post-period 1	-4.43***	-0.0374***	2.80*
	(1.02)	(0.0025)	(1.36)
PCP retired*Post-period 2	-7.64***	-0.0374***	-1.32
	(1.24)	(0.0028)	(1.61)
Observations	8,665,305	8,665,305	5,429,430
R^2	0.29	0.24	0.33
Baseline mean	86.85	0.6385	136.01

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

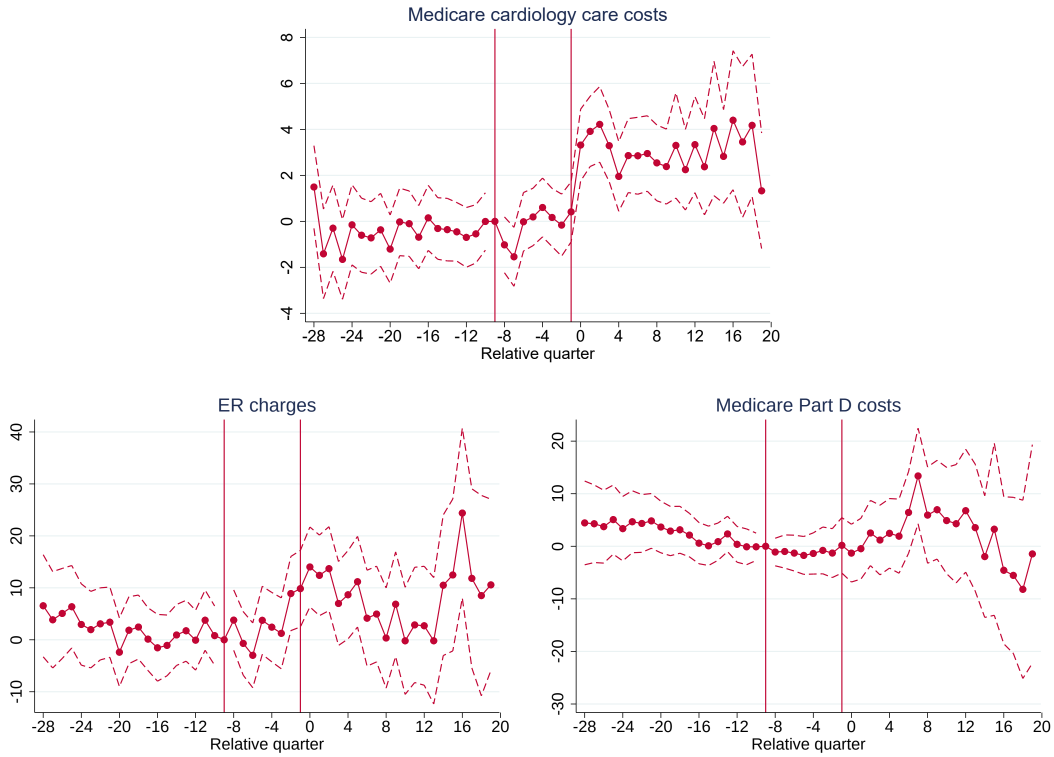


Figure 3: Effect of PCP Retirement on Other Forms of Health Care Utilization

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1. All costs are measured in 2010 USD.

Table 3: Effect of PCP Retirement on Other Forms of Health Care Utilization

	Cardiology costs	**ER costs**	**Prescription drug costs**
PCP retired*Lead-period	0.10	1.77	-2.53
	(0.31)	(1.81)	(1.83)
PCP retired*Post-period 1	3.55***	9.56***	-0.48
	(0.48)	(2.82)	(2.87)
PCP retired*Post-period 2	3.18***	3.41	3.94
	(0.55)	(3.63)	(4.04)
Observations	8,665,305	8,665,305	8,665,305
R^2	0.11	0.12	0.43
Baseline mean	40.08	152.81	224.59

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

to their PCP visits (either because replacement PCPs are making more referrals or patients are voluntarily seeing specialists more often). Figure A2 shows the increases in cardiologist visits by patients without and with a new PCP. I find that both groups increase cardiologist visits, while the former group (channel 1) is twice as likely as the latter (channel 2) to visit a cardiologist.

II. Emergency care

The relationship between primary care and emergency care among the elderly population is complicated. Although most studies claim that primary care utilization can reduce ER visits for the general population (Bradley et al. 2017), a few studies find that primary care utilization has limited impact on ER utilization among older adults (Hunold et al. 2014).

Unlike the effects of PCP retirement on speciality care utilization, emergency care utilization shows two different patterns, as seen in Figure 3 and Table 3. First, ER costs start to increase two quarters before PCPs retire. Second, the increase in ER costs is mainly a short-term effect, although there is suggestive evidence that it will rebound four years after PCP retirement. Specifically, in the two quarters prior to PCP retirement, ER costs per capita increase by about $10 (6.5%) per quarter. After PCP retirement, ER costs per capita further increase by $9.56 per quarter in the first 1.5 years, a 6.3% increase relative to the baseline. After that, ER costs return to the baseline level, although there seems to be another spike four years after PCP retirement.[25]

III. Prescription drugs

The bottom right graph in Figure 3 documents the effect of PCP retirement on prescription drug costs. As is shown, there is little disruption in prescription drug use around the time of PCP retirement. Although prescription drug costs slightly increase after two years and then decrease after three years, almost none of the changes are statistically significant, as shown in the last column in Table 3. When looking at changes at the extensive and intensive margins in Figure A3, this average cost change is mainly driven by the changes at the intensive margin. Overall, prescription drug use is generally not affected by PCP retirement.

IV. Medical tests

As PCP retirement naturally leads patients to switch physicians, it is likely that new physicians will order medical tests to thoroughly examine their new patients, due to difficulty accessing pa-

[25] Only patients whose initial PCP retired before quarter 4 of 2011 and who were still alive can be observed for more than four years. Therefore, the estimates become noisier when relative quarters are large.

tients' previous medical records, unusual patterns that they notice in patients, or preventive care. Therefore, I expect an increase in the use of medical tests.

Figure 4 shows that both diagnostic and imaging tests start to increase in the quarter right before a PCP's retirement date and reach a peak in the second quarter after PCP retirement, with an approximately 4.2% increase in both diagnostic and imaging tests. Then, both types of tests gradually decline and basically return to the baseline level 1.5 years after PCP retirement, especially the imaging tests, except for a spike four years after PCP retirement. The dynamic pattern of diagnostic and imaging tests is fairly similar to that of emergency care and is mainly a short-term effect. As shown in Table 4, in the first 1.5 years, diagnostic and imaging tests increase by 10.58 percentage points (2.5%) and 5.28 percentage points (3.7%), respectively.

Along with the increase in medical test utilization, the bottom graph in Figure 4 shows a surge in the detection of new chronic conditions from the quarter right before PCP retirement. At its peak in relative quarter 2, patients are 1.5 percentage points (11.9%) more likely to be diagnosed with at least one new chronic condition compared to the baseline. As shown in Table 4, the likelihood of patients being diagnosed with a new chronic condition increases by 0.99 percentage points (7.9%) in the first 1.5 years after PCP retirement. After two years, the likelihood returns to the previous level, except for a temporary increase at the beginning of the fourth post-retirement year. In addition to this aggregate effect, details on specific chronic disease detection are shown in Section 5.3.

V. Inpatient care

Hospital stays are very expensive in the US, with an average cost of $30,000 for a three-day stay. Therefore, if hospitalizations increase, total medical costs will also increase significantly. Figure A4 and Table A5 show how PCP retirement affects patients' inpatient care utilization.

In general, inpatient care remains at a similar level before PCP retirement but rises in the 1.5 years after PCP retirement. The probability of being hospitalized increases by 0.22 percentage points (2.9%) on average in the first 1.5 years and then returns to the baseline level, except for the spike four years after PCP retirement. To better understand the increase in hospitalizations, I look separately at the impact of PCP retirement on two main sources of hospital admissions: physician referral and ER. Although both sources contribute to the increase in hospitalizations, hospitalizations through ER account for 55% of the increase. Relative to each baseline, the percent

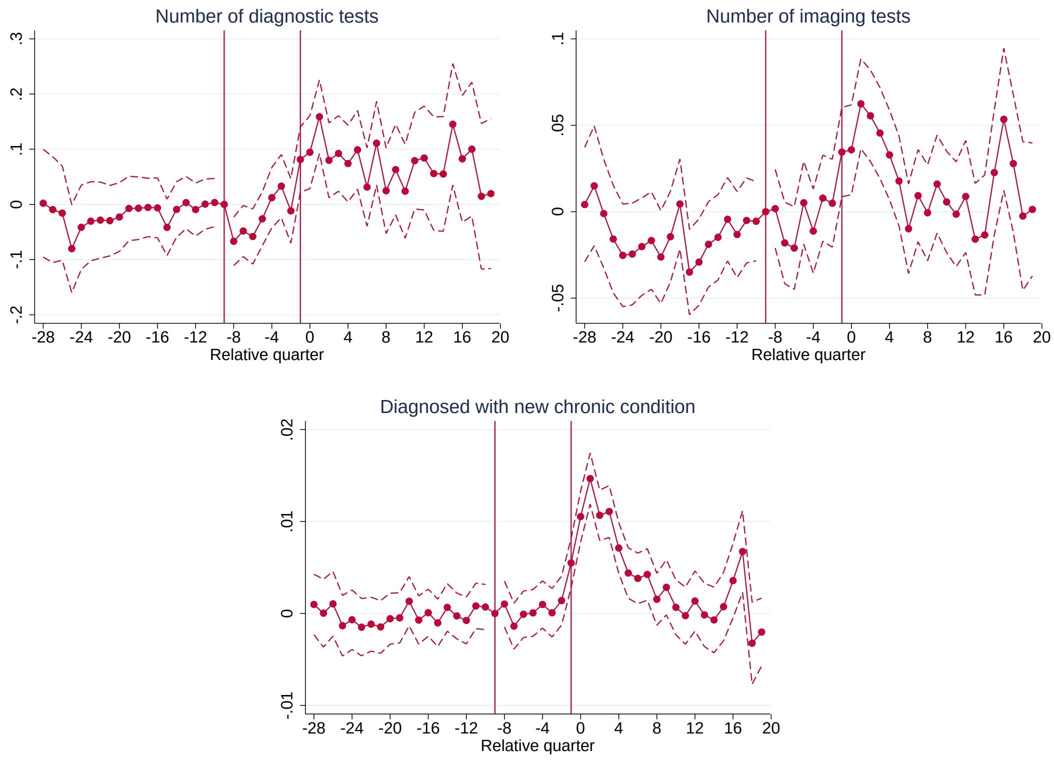


Figure 4: Effect of PCP Retirement on Medical Test Utilization and Diagnosis

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1.

Table 4: Effect of PCP Retirement on Medical Test Utilization and Diagnosis

	No. Diagnostic tests	**No. Imaging tests**	**Has new diagnosis**
PCP retired*Lead-period	-0.0042	0.0116*	0.0009
	(0.0187)	(0.0054)	(0.0005)
PCP retired*Post-period 1	0.1058***	0.0528***	0.0099***
	(0.0281)	(0.0072)	(0.0007)
PCP retired*Post-period 2	0.0666*	0.0158*	0.0021**
	(0.0337)	(0.0079)	(0.0007)
Observations	8,665,305	8,665,305	8,665,305
R^2	0.36	0.13	0.02
Baseline mean	4.2623	1.4153	0.1258

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

increase in physician-referred hospitalizations is larger than that of hospitalizations via ER: 3.7% versus 2.4% in the first 1.5 years after PCP retirement.

4.3 Total Medicare Costs

Finally, I examine the effect of PCP retirement on total Medicare costs in Figure 5 and Table 5. Although there is an anticipatory effect on primary care and emergency care utilization, the total per capita (Original) Medicare costs remain at a similar level as the baseline during the anticipatory period. Total costs begin to increase after PCP retirement, and they increase by $95.27 (3.9%) per quarter on average in the first 1.5 years. Since PCP retirement results in short-term effects on most forms of health care in the first 1.5 years, except for the persistent decline in primary care utilization and permanent increase in cardiology care utilization, it is not surprising to find that the effect on total medical costs follows the same pattern. On average, PCP retirement results in a $571.62 ($95.27*6) increase in total per capita (Original) Medicare costs.

In addition, Figure 5 and Table 5 show separately the effects of PCP retirement on the average per capita outpatient costs and inpatient costs. In the initial three quarters after PCP retirement, outpatient care and inpatient care contribute almost equally to the increase in overall medical costs, while in the fourth to sixth quarters, inpatient care is the main driver of the increase in total medical costs. In general, in the first 1.5 years after a PCP retires, quarterly per capita outpatient costs increase by $39.68 (3.2%), and quarterly per capita inpatient costs increase by $40.00 (4.0%).

4.4 Robustness Checks

Table A6 shows the estimates using the alternative matched sample and treatment group only. As matched sample 2 is based on a matched control group whose initial PCP retired after quarter 4 of 2015, there is almost no anticipatory effect in 2006–2015 for these control individuals. Therefore, the estimated effect sizes for matched sample 2 are expected to be larger than those from the main matched sample. In addition, as shown in Table 1, the whole treatment group is sicker and poorer than the matched sample, and thus PCP retirement is likely to generate greater impact on them. Table A6 confirms these conjectures. Compared to Tables 2–5, the effect sizes of matched sample 2 and the treatment group only are generally larger, especially for the latter. My analysis based

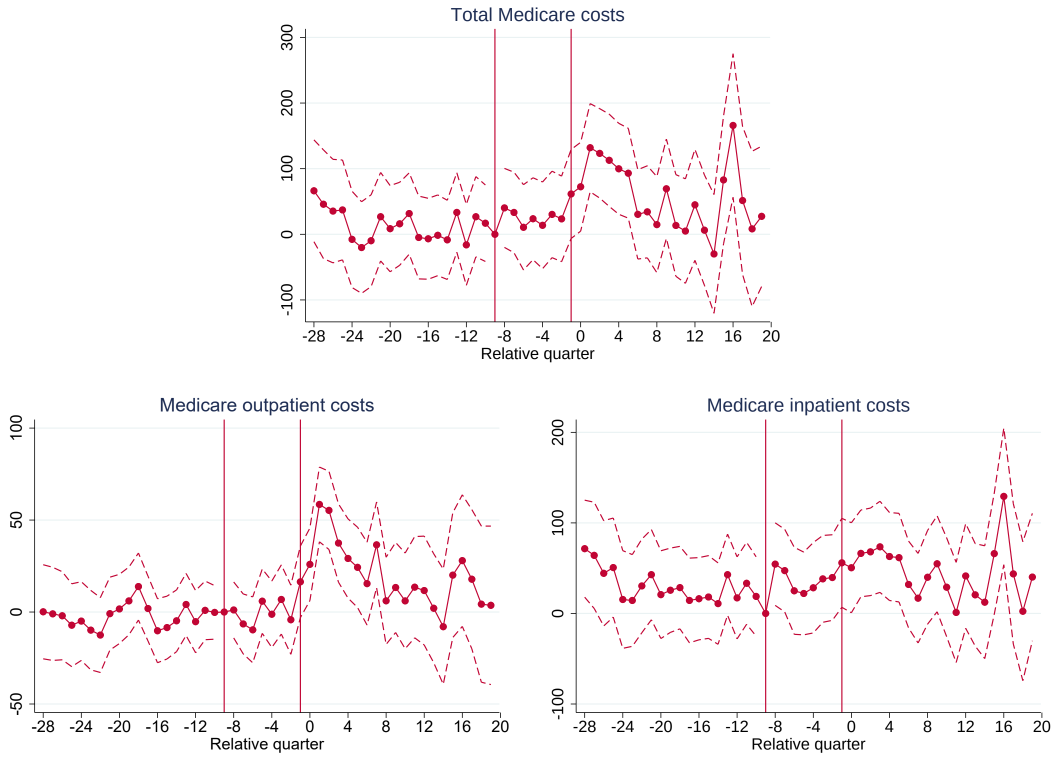


Figure 5: Effect of PCP Retirement on Medicare Costs

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1. All costs are measured in 2010 USD.

Table 5: Effect of PCP Retirement on Medicare Costs

	Total costs	**Outpatient costs**	**Inpatient costs**
PCP retired*Lead-period	19.95	2.02	15.82
	(14.16)	(5.19)	(9.60)
PCP retired*Post-period 1	95.27***	39.68***	40.00***
	(18.06)	(7.23)	(11.67)
PCP retired*Post-period 2	23.36	15.31	11.02
	(20.04)	(8.67)	(12.50)
Observations	8,665,305	8,665,305	8,665,305
R^2	0.14	0.31	0.08
Baseline mean	2470.34	1230.76	1003.77

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

on the main sample generates the lower bound of the estimated effects of PCP retirement on the elderly Original Medicare beneficiaries, and Panel B (treatment group only) of Table A6 generates the upper bound of the estimated effects. Combining the results from my main sample and these two alternative samples, I obtain the following ranges of the main effect sizes in the first 1.5 years after PCP retirement: the estimated change in quarterly per capita Medicare costs for primary care is between $-$\$4.43 and $-$\$6.37 ($-$5.1% to $-$7.5%); the estimated change in quarterly per capita Medicare costs for inpatient care is between \$40.00 and \$88.25 (4.0% to 8.8%); and the estimated change in quarterly per capita total Medicare costs is between \$95.27 and \$153.11 (3.9% to 6.2%).

4.5 Summary

In sum, among Original Medicare patients aged 65 and over, PCP retirement results in a permanent decline in primary care utilization and a permanent increase in specialty care utilization, but it mainly has short-term effects on emergency care, medical tests, and inpatient care utilization. As a result, the increase in total Medicare costs is also mainly a short-term response. In addition, although we may suspect that patients would anticipate the retirement of their PCP, I only find moderate anticipatory effects on primary care utilization and emergency care utilization. The size of the anticipatory effect on primary care is only about 1/6 of the disruption effect after PCP retirement.[26] In addition, the anticipatory effect on ER utilization appears only in the last two quarters prior to PCP retirement.

Given the estimates above, a normal PCP retirement (PCP retiring at age 60 or over) incurs about a \$57,200 to \$91,900 (in 2010 USD) increase in Original Medicare expenditure for the elderly beneficiaries, as a retired PCP on average has 20 dependent patients in the 20% Original Medicare sample, and the estimated Medicare cost increase is between \$572 (\$95.27*6) and \$919 (\$153.11*6) per patient in the first 1.5 years after PCP retirement.

Between 2010 and 2013, on average 2,200 accountable PCPs retired at age 60 or over in each year in my sample. Therefore, each year PCP retirement due to aging caused about a \$126 million (\$57,200*2,200) to \$202 million (\$91,900*2,200) (in 2010 USD) increase in Original Medicare costs. In 2010, total Medicare spending was \$516 billion, and Original Medicare spending was

[26]For primary care, I treat the average effect between quarters -8 and -2 as the anticipatory effect, because primary care utilization surges mechanically in quarter -1 by construction.

$338 billion.[27] Therefore, normal PCP retirement-incurred costs account for 0.04–0.06% of the Original Medicare spending. Although this is a small share, the absolute amount is not negligible.[28]

According to the Association of American Medical Colleges (2020), there were 228,100 active PCPs in 2018. Among them, 16% were aged 65–75, and 27% were aged 55–64, so more than a third of them are likely to retire within a decade. Given that a normal PCP retirement results in a $57,200 to $91,900 increase in Original Medicare expenditure for the elderly beneficiaries, the retirement of these 75,273 (228,100*1/3) PCPs will cost Medicare at least $4.3 billion ($57,200*75,273) (in 2010 USD) from 2018 to 2028.[29] Of this $4.3 billion, about $913 million (21%) is due to the increase in retirement rate as a result of the aging physician workforce from 2013 to 2018.[30]

5 Results: Effects on Health Care Quality

5.1 Mortality

Mortality is a crude measurement of an individual's health status and a drastic outcome. Even though PCP retirement might have some negative effects on patients' health outcomes, it seems unlikely that a disruption in primary care would cause an immediate plummet in patients' health status and thus lead to fatal outcomes. Similar to the finding in Tu (2017) regarding the departure of specialists, I find no effect of PCP retirement on patient mortality, as shown in Figure A5 and Table A7. In addition to the impact on mortality rate, column 3 in the output table reports results from the Cox Proportional Hazard model, as shown by equation (3). Consistent with the results from the linear probability model, PCP retirement also has no effect on the hazard of death.

[27] https://www.kff.org/medicare/issue-brief/the-facts-on-medicare-spending-and-financing/

[28] If we take into account the costs due to the early retirement of PCPs, the costs would be even higher.

[29] Note that this is the lower bound of the estimated Medicare costs of PCP retirement due to physician aging, because the number of PCPs from the AMA Physician Masterfile does not include non-physician PCPs. In addition, spending on Medicare Advantage is not included, and the beneficiaries included in the analysis are only those who were aged 65 and over, had full coverage of Medicare Part A and B, and lived in the same HSA in 2006–2015.

[30] In 2013, the share of PCPs between the ages 55 and 75 constituted 36% of the active workforce (Association of American Medical Colleges 2015). Therefore, the share of near-retirement PCPs increased by about 7% from 2013 to 2018. Given that the number of active PCPs in 2018 was 228,100, this implies that 15,967 (228,100*7%) of the predicted PCP retirements are as a result of the increase in the retirement rate from 2013 to 2018, which explains 21% (15,967/75,273) of the projected Original Medicare costs and translates into a projected $913 million ($57,200*15,967) increase in Original Medicare costs due to physician aging.

5.2 Potentially Avoidable Hospitalizations

Hospitalizations due to ACSCs are wasteful and avoidable if patients receive effective ambulatory care. Therefore, a higher hospitalization rate due to ACSCs suggests lower ambulatory care quality (Agency for Healthcare Research and Quality 2001). Figure 6 shows the impact of PCP retirement on quarterly hospitalization rates due to four types of ACSCs. In general, there is little impact of PCP retirement on potentially avoidable hospitalizations, except for the increase in hospitalizations due to congestive heart failure in the second post-retirement quarter and in the fifth year after PCP retirement. Table 6 indicates that the hospitalization rate due to heart failure increases by 0.14 percentage points (9.3%) in the first 1.5 years and 0.18 percentage points (11.9%) in the rest of the period after PCP retirement. In addition, PCP retirement results in a 4.4% increase in the hospitalization rate due to acute ACSCs in the first post-period and a 10.7% decrease in the hospitalization rate due to diabetes in the lead period; however, both effects are only significant at the 10% level.

5.3 Diagnosis of New Chronic Diseases

Figure 4 and Table 4 in Section 4.2 demonstrate the increase in the overall detection of new chronic diseases. Although the above findings suggest a slight decline in the quality of care in managing certain diseases after PCP retirement, it seems unlikely that patients will develop a new chronic condition immediately after their PCP retires. In addition, the pre-trend during the baseline period and the trend during the lead period are both flat, which rules out the possibility that retiring PCPs are delinquent and shift the responsibility to their successors. Therefore, the increase in the detection of new chronic diseases can be attributed to new physicians' observation and judgment. Although switching physicians may interfere with the continuity of care, it also helps patients to get a fresh opinion, which may result in better patient outcomes.

Only knowing the increase in the overall detection of new chronic diseases is not enough, as it is important to know which diseases are driving the average increase and whether the detection of these diseases is beneficial for patients. Therefore, Figure 7, Figure A6, and Figure A7 reveal the effects on the detection of 27 different chronic diseases in the CMS data. The increase in the detection of the nine diseases shown in Figure 7 explains most of the increase in the detection of

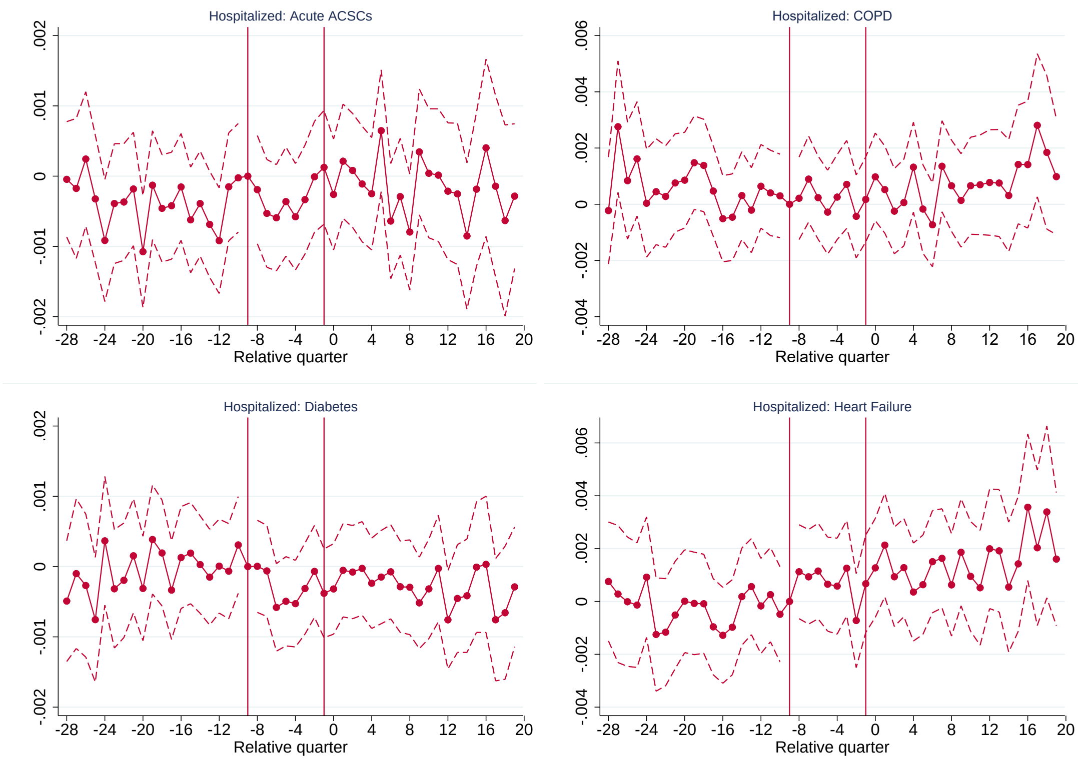


Figure 6: Effect of PCP Retirement on Potentially Avoidable Hospitalizations

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1.

Table 6: Effect of PCP Retirement on Potentially Avoidable Hospitalizations

	Acute	**COPD**	**Diabetes**	**Heart failure**
PCP retired*Lead-period	0.0000	-0.0001	-0.0003*	0.0010*
	(0.0001)	(0.0003)	(0.0001)	(0.0004)
PCP retired*Post-period 1	0.0004*	0.0001	-0.0001	0.0014**
	(0.0002)	(0.0004)	(0.0001)	(0.0005)
PCP retired*Post-period 2	0.0001	0.0003	-0.0003	0.0018***
	(0.0002)	(0.0004)	(0.0002)	(0.0005)
Observations	8,593,052	2,184,491	2,902,753	2,389,411
R^2	0.05	0.08	0.04	0.09
Baseline mean	0.009	0.0103	0.0028	0.0151

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Only observations before October 1, 2015 are included in the analyses due to the switch from ICD-9 to ICD-10 code in October 2015. For chronic ACSCs, only data from calendar year $t + 1$ are included in the analyses after patients were first diagnosed with a chronic condition in year t. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

any new chronic disease.[31] Most of these diseases evolve gradually as an individual ages and may be hard for both physicians and patients themselves to detect due to slowly developing symptoms (Weimer and Sager 2009; Allan et al. 2014). Although not all of the increases in diagnoses are clinically meaningful, and the increased diagnosis of some diseases seems puzzling, early detection of certain diseases, such as depression, hyperlipidemia, osteoporosis, Alzheimer's disease, related disorders or senile dementia, and hypertension, are beneficial for patients in terms of getting timely treatment, reducing long-term costs, and/or having better health outcomes.[32]

Although it is hard to quantify the long-term savings and health benefits of these early diagnoses, Weimer and Sager (2009) use data from Wisconsin and estimate that the early diagnosis and treatment of Alzheimer's disease and related dementia can generate $10,000 net federal fiscal savings per patient. Figure 7 shows that the diagnosis rate of Alzheimer's disease, related disorders, or senile dementia increases by 0.001 for at least four quarters after PCP retirement, so the total savings from such an increase in early detection is $40 ($10,000*0.001*4) per patient. Compared to the total increase in Medicare costs of $572 per patient, net federal savings of early detection of Alzheimer's disease offset 7% ($40/$572) of the overall increase in Medicare costs due to PCP retirement.[33]

Given that having a new physician can lead to early detection of certain chronic diseases and the potential benefits of such early detection, elderly patients may consider seeking a second opinion when when they are uncertain about their health, especially when experiencing symptoms related to dementia or depression.

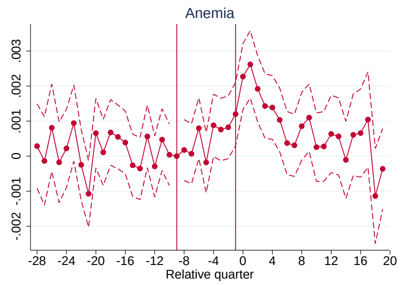
5.4 PCP Quality

The above evidence demonstrates that PCP retirement leads to an increase in Medicare costs and an improvement in the detection of chronic diseases. In the following, I document the underlying changes in PCP quality, as measured by PCPs' adherence/contribution to recommended preventive

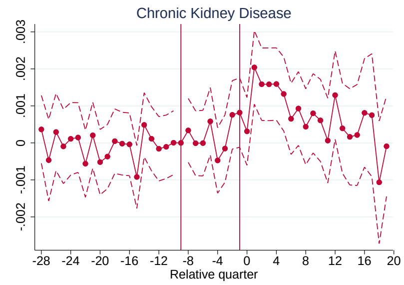
[31] Figure A6 shows a moderate increase in the detection of common chronic diseases, such as diabetes, COPD, and congestive heart failure, but not as sharp of an increase as among the diseases in Figure 7. Figure A7 shows that there is no impact of PCP retirement on the detection of cancers.

[32] This conclusion is drawn by consulting several physicians and is also confirmed by Leifer (2003), Tucci (2006), and Park and Unützer (2011).

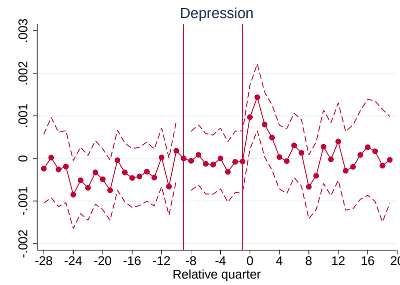
[33] This 7% is a lower bound, because the federal savings are net of the diagnosis and treatment costs for Alzheimer's disease and related dementia. In addition, Weimer and Sager (2009) also estimate that the mean net social benefits are $94,000 and the mean net state benefits are $5,000, which I do not take into account when calculating the benefit.



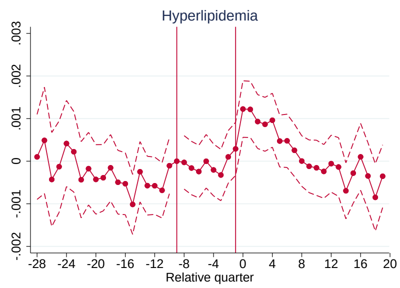
(a) Baseline mean = 0.0134



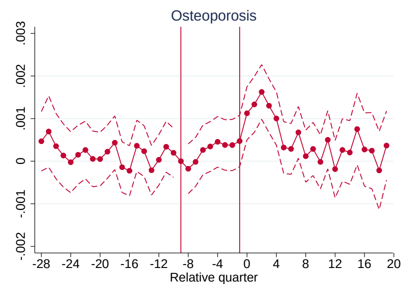
(b) Baseline mean = 0.0107



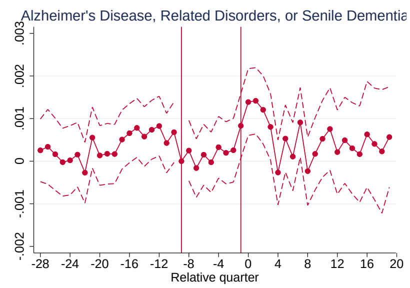
(c) Baseline mean = 0.0073



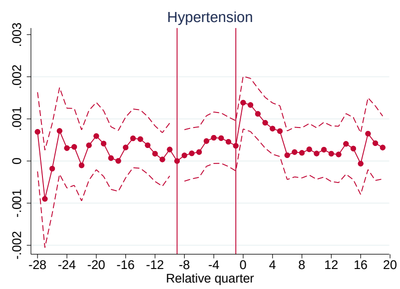
(d) Baseline mean = 0.0109



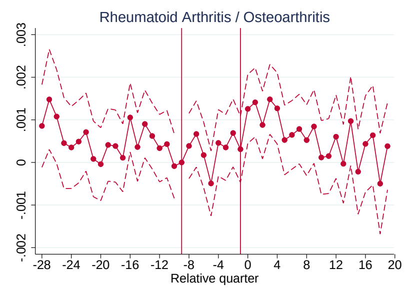
(e) Baseline mean = 0.0057



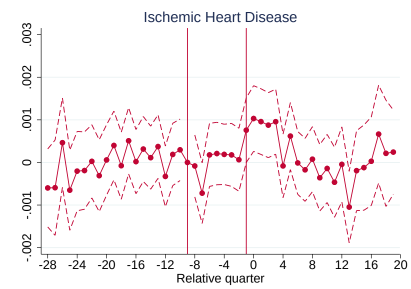
(f) Baseline mean = 0.0072



(g) Baseline mean = 0.0105



(h) Baseline mean = 0.0111



(i) Baseline mean = 0.0099

Figure 7: Diagnosed with a New Chronic Disease – Major Effect

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1. The outcome variable is whether a patient is diagnosed with a certain chronic condition in a relative quarter. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9.

care procedures.

Before examining the changes in PCP quality, it should be noted that not all patients in my sample find a new PCP. Among patients still alive upon entering the lead period, about 9% of them do not find a new accountable PCP. Those who do find one tend to make the change within a year of their PCP's retirement. Figure A8 (a) shows the time taken to find a new PCP among my main patient sample. The switch to a new PCP increases discontinuously in the last quarter before PCP retirement and more abruptly in the first quarter after PCP retirement. Among patients who find a replacement PCP, about 90% of them do so successfully by the end of the first year.

Figure 8 illustrates the changes in patients' accountable PCP's quality. The first two graphs suggest that patients can generally find a replacement PCP of higher quality in diabetes management quickly. However, it takes time to find a replacement PCP who adheres better to flu vaccination, and the longer it takes, the higher value-added a replacement PCP has on flu vaccination. In general, the effect sizes of the improvement in PCP quality are relatively small, as shown in Table 7. Adherence to the HbA1c test and lipid test increases by about 0.07 (0.0052/0.0736) and 0.12 (0.0096/0.0827) SD, respectively, while the increase in flu vaccination adherence is only 0.03 (0.0012/0.0419) SD.[34]

5.5 Robustness Checks

Table A8 shows the estimated effects on the alternative matched sample and the treatment group only. In general, the effect sizes are still slightly larger than those from the main matched sample, and the significance levels mostly remain the same. All the results have the same interpretation as what I find from the main analysis.

In sum, I find that PCP retirement has no impact on patients' mortality rate, has little impact on potentially avoidable hospitalizations, and improves the early diagnosis of chronic diseases among elderly patients. Among patients who find a replacement PCP, there is an improvement in their PCP's quality, but only slightly. In addition, although there is some anticipatory behavior in health care utilization before PCPs retire, the quality of care is, in general, not affected until after PCPs retire.

6 Heterogeneity Analyses

The above two sections demonstrate the average effects of PCP retirement on patient outcomes. This section explores whether there are heterogeneous effects among different patients and what

[34]Nevertheless, the improvement in accountable PCP's quality may lead to a long-run improvement in care quality, as it has been shown that patients who switch to higher quality PCPs are much more likely to receive higher quality care (Fadlon and Van Parys 2020).

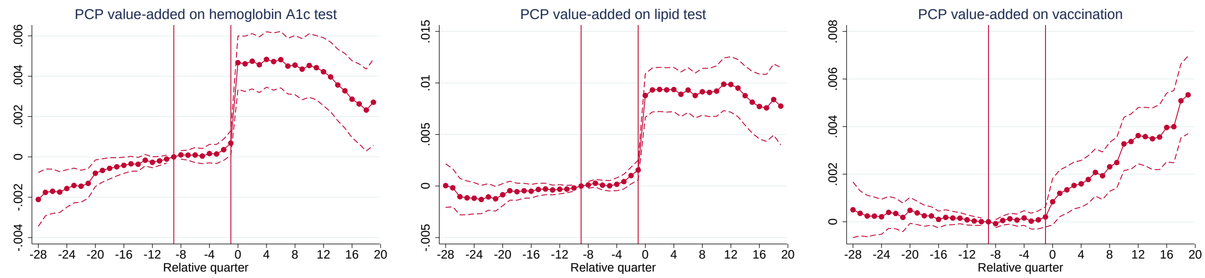


Figure 8: Changes in Accountable PCP's Quality

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1.

Table 7: Changes in Accountable PCP's Quality

	HbA1c	**Lipid**	**Flu vaccination**
PCP retired*Lead-period	0.0007**	0.0009*	-0.0001
	(0.0003)	(0.0004)	(0.0002)
PCP retired*Post-period 1	0.0052***	0.0096***	0.0012*
	(0.0007)	(0.0012)	(0.0005)
PCP retired*Post-period 2	0.0047***	0.0094***	0.0027***
	(0.0008)	(0.0012)	(0.0005)
Observations	4,950,994	4,950,994	5,021,960
R^2	0.87	0.81	0.81
Baseline mean	-0.0047	-0.0068	0.003
Baseline SD	0.0736	0.0827	0.0419

Notes: The table reports DID estimates from equation (2). The outcome variables are accountable PCPs' adherence to the three recommended procedures. Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Only relative quarters with at least one visit to a beneficiary's accountable PCP are kept for analysis. The numbers of observations are lower for value-added on HbA1c and lipid test, because a small share of PCPs did not have enough diabetes patients to calculate a value-added on diabetes management. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Baseline SD is the standard deviation of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

we can learn from these heterogeneous effects to better inform policies.

Specifically, I test the following three hypotheses. First, although there is no agreement on whether solo or group practitioners are more efficient and productive in providing care (Gaynor and Pauly 1990; DeFelice and Bradford 1997; Rebitzer and Votruba 2011), it naturally costs less to switch within a group practice than to switch between practices. Therefore, I expect patients whose retired PCP is a solo practitioner to experience higher switching costs. Second, when physicians leave a place or retire, they are required to notify their state medical board. However, notification to patients is not always mandatory. Therefore, I expect that beneficiaries in states where patient notification is mandatory are likely to be better informed and more prepared for the retirement of their PCPs and thus may experience less disruption in care. Third, although there is no simple relationship between the supply of PCPs and primary care utilization (Goodman et al. 2010), Baicker and Chandra (2004) show that states with more general practitioners use more cost-effective care and have lower Medicare spending, and Basu et al. (2019) show that higher PCP density is associated with lower mortality rate. As such, I expect patients in primary care HPSAs to experience a greater increase in medical spending due to lower availability of replacement PCPs.

I examine these three heterogeneities using equation (4):

$$\begin{aligned} y_{it}^{(k)} &= \theta \cdot D_i * Lead + \beta_1 \cdot D_i * Post1 + \beta_2 \cdot D_i * Post2 \\ &= +\theta^H \cdot D_i * Lead * Hetero_{it} + \beta_1^H \cdot D_i * Post1 * Hetero_{it} + \beta_2^H \cdot D_i * Post2 * Hetero_{it} \\ &= +Hetero_{it} + \gamma X_{it} + \alpha_i + \sigma_t + \varepsilon_{it}, \end{aligned} \tag{4}$$

where $Lead = 1(t_i^* - 8 \leq k \leq t_i^* - 1)$, $Post1 = 1(t_i^* \leq k \leq t_i^* + 5)$, and $Post2 = 1(k \geq t_i^* + 6)$; t_i^* is the quarter when patient i's initial PCP retired. $D_i = 1$ if patient i's initial PCP retired between 2010 and 2013. $Hetero_{it} = 1$ if (1) patient i's initial PCP is a solo practitioner, (2) patient i's initial PCP practices in a state that requires physician departure notice to patients, or (3) patient i resides in a county fully designated as a primary care HPSA in year t, respectively.[35] Standard errors are clustered at the initial accountable PCP level.

[35]There are sample exclusions due to missing data. For the first analysis, I exclude PCPs who had both solo and group practice affiliations in the 2007 MPIER and PCPs with missing affiliations. For the second analysis, I exclude five states that have no information on physician departure notice to patients. Table A9 lists the physician departure notice request by each state. For the third analysis, county-years without HPSA designation information are excluded.

Table A10 shows summary statistics of the matched treatment group used in each heterogeneity analysis. In general, patients in a group practice, with mandatory departure notice for PCPs, or living in a partial or non-HPSA county are better off than their counterparts in a solo practice, without mandatory departure notice for PCPs, or living in a primary care HPSA. Specifically, compared to patients in a group practice (column [2]), patients seeing solo PCPs (column [1]) are relatively older, less likely to be white, more likely to be dually eligible, and sicker; their PCPs are also older, less likely to have mandatory departure notice, and of lower quality. Next, compared to patients with a PCP that is not required to give a departure notice (column [4]), patients with mandatory PCP departure notice (column [3]) are slightly younger and less likely to be dually eligible; their PCPs are more likely to work in a group practice and be of slightly higher quality. Finally, patients in HPSAs (column [5]) are slightly older, less likely to be white, more likely to be dually eligible, and sicker; however, their initial PCPs tend to be of slightly higher quality on diabetes management.

Table 8 shows the results on health care utilization. Columns (1)–(6) show the impact on Medicare costs, and columns (7) and (8) show the impact on the number of medical tests. Panel A demonstrates that the retirement of a solo PCP results in a larger decline in primary care utilization (although not statistically significant in costs) and a larger increase in utilization of all other forms of care.[36] As a result, retirement of a solo PCP leads to an over $150 increase in quarterly per capita Medicare costs compared to retirement of a PCP working in a group practice. In particular, the increase in ER and inpatient care utilization is almost solely driven by the retirement of solo PCPs. Panel B shows that physician departure notice can greatly alleviate the disruption in primary care (column [1]) and mitigate the increase in hospitalizations (column [5]). Moreover, a smoother switch from a retired PCP to a replacement PCP may result in a long-run reduction in total Medicare spending ($PCP\ retired * Post2 * Request$), as shown in column (6). Panel C reveals that patients living in a county that is fully designated as an HPSA experience a larger disruption in primary care and greater substitution with other forms of care.[37] As a consequence, a PCP retirement in an HPSA county results in an over $90 increase in quarterly per capita Medicare

[36] The estimates on the extensive margin – whether a patient has any primary care visit in a quarter – are -0.03 for both $PCP\ retired * Post1 * Solo$ and $PCP\ retired * Post2 * Solo$ and are significant at the 1% level.

[37] Similar to the estimates from Panel A column (1), although the reduction in average costs is not statistically significant, the estimates of the extensive margin for $PCP\ retired * Post1 * HPSA$ and $PCP\ retired * Post2 * HPSA$ are -0.01 and -0.02, significant at the 10% and 1% level, respectively.

spending compared to counties that are partially or not designated as an HPSA.[38]

Table 9 shows the results for changes in the quality of care. Panel A columns (6)–(8) show that patients with a retired solo PCP are more likely to to find a replacement PCP of higher quality. This is not surprising, as patients in a group practice are more likely to switch PCPs internally, and physicians affiliated with the same group practice tend to be of similar quality. In addition, patients with a retired solo PCP are more likely to be diagnosed with a new chronic condition (column [5]). Although the coefficient is only significant at the 10% level, the magnitude is not negligible: patients with a retired solo PCP are 44.3% more likely to be diagnosed with a new chronic condition than patients with a retired PCP working in a group practice. However, changes in hospitalization rates due to ACSCs are similar between patients with a retired solo PCP and those with a retired PCP that is part of a group practice, except that patients with a retired solo PCP have a lower hospitalization rate due to congestive heart failure after the retirement of their PCP, potentially due to their greater utilization of cardiology care after their solo PCP retires.

Table 8 shows that state-level mandates on physician departure notice can mitigate the disruption in care. Column (1) of Panel B in Table 9 further demonstrates this: although patients in states without mandatory physician departure notice experience an increase in hospitalization rate due to acute ACSCs, patients in mandatory states do not. Patients also have lower hospitalization rates due to COPD and diabetes in states that require departure notice, although the effects are not statistically significant. However, patients in states that require physician departure notice are 17.5% less likely to be diagnosed with a new chronic condition. Regarding the quality of replacement PCPs, there is little change in all three value-added measures. Finally, although Panel C in Table 8 shows that patients in an HPSA county experience a greater disruption in care and an increase in medical costs, Panel C in Table 9 shows that there is little difference between HPSA counties and non- or partially HPSA counties in terms of the change in quality of care after PCP retirement.

In sum, the solo/group practice affiliation of retired PCPs, state-level mandates on physician departure notice, and PCP availability all influence how PCP retirement affects patients' health care utilization. Patients in a group practice experience less disruption in care, as do patients in states

[38]In addition, Figure A8 shows that patients with a retired solo PCP and patients living in a primary care HPSA are less likely to find a replacement PCP, whereas patients who receive a mandated physician departure notice are more likely to find a replacement PCP.

Table 8: Heterogeneity Analysis: Health Care Utilization

	(1) Primary care	(2) Cardiology	(3) ER	(4) Drug	(5) Inpatient	(6) Total costs	(7) Diagnostic tests	(8) Imaging tests
Panel A: Solo/Group								
PCP retired*Lead	0.20	0.19	-4.96*	-3.37	-20.95	-32.53	-0.0001	0.0018
	(0.85)	(0.37)	(2.17)	(2.39)	(11.88)	(17.61)	(0.0254)	(0.0069)
PCP retired*Post1	-1.30	2.94***	1.50	-4.37	5.68	48.21*	0.0538	0.0451***
	(1.27)	(0.59)	(3.51)	(3.66)	(14.41)	(22.58)	(0.0360)	(0.0091)
PCP retired*Post2	-3.86**	3.05***	-6.60	-0.01	-18.69	-11.21	-0.0063	0.0181
	(1.39)	(0.64)	(4.39)	(5.15)	(15.50)	(24.90)	(0.0417)	(0.0098)
PCP retired*Lead*Solo	-0.66	-1.55*	24.56***	6.88	100.36***	150.88***	0.0084	0.0397**
	(1.37)	(0.72)	(4.66)	(4.38)	(23.48)	(34.39)	(0.0444)	(0.0130)
PCP retired*Post1*Solo	-3.65	2.52	30.44***	9.98	110.06***	168.34***	0.2049**	0.0556**
	(2.41)	(1.37)	(7.01)	(5.77)	(28.44)	(43.86)	(0.0708)	(0.0176)
PCP retired*Post2*Solo	-4.93	1.53	43.72***	7.24	132.00***	191.48***	0.2675***	0.0495**
	(2.74)	(1.47)	(8.80)	(8.30)	(26.16)	(42.63)	(0.0785)	(0.0169)
Observations	6,529,560	6,529,560	6,529,560	6,529,560	6,529,560	6,529,560	6,529,560	6,529,560
Baseline mean	85.96	39.90	149.43	216.00	974.87	2404.29	4.2771	1.3989
Panel B: Whether state requires physician departure notice								
PCP retired*Lead	-1.31	0.24	-1.94	2.88	69.47***	73.95***	-0.0554	0.0148
	(1.11)	(0.48)	(2.77)	(2.65)	(15.70)	(22.39)	(0.0296)	(0.0082)
PCP retired*Post1	-9.60***	3.72**	3.65	7.05	118.77***	192.95***	0.0819	0.0724***
	(1.64)	(0.68)	(4.06)	(4.41)	(18.97)	(28.30)	(0.0440)	(0.0110)
PCP retired*Post2	-15.06***	3.95***	-9.33	17.42**	98.31***	126.12***	0.0866	0.0272*
	(1.84)	(0.86)	(5.19)	(6.12)	(18.44)	(29.59)	(0.0507)	(0.0115)
PCP retired*Lead*Request	1.31	-0.12	6.17	-9.18**	-89.13***	-91.07***	0.0891*	-0.0045
	(1.32)	(0.59)	(3.38)	(3.12)	(18.46)	(26.84)	(0.0360)	(0.0101)
PCP retired*Post1*Request	8.52***	-0.19	9.23	-12.66**	-131.05***	-165.50***	0.0544	-0.0319*
	(1.98)	(0.89)	(5.09)	(4.83)	(21.56)	(32.85)	(0.0521)	(0.0133)
PCP retired*Post2*Request	12.34***	-1.20	20.19**	-21.71**	-147.44***	-175.42***	-0.0307	-0.0181
	(2.10)	(0.98)	(6.18)	(6.84)	(20.21)	(32.72)	(0.0590)	(0.0131)
Observations	8,410,946	8,410,946	8,410,946	8,410,946	8,410,946	8,410,946	8,410,946	8,410,946
Baseline mean	87.35	40.51	154.54	224.26	1011.84	2485.35	4.2816	1.4228
Panel C: Primary care HPSA								
PCP retired*Lead	-1.73*	-0.20	-2.61	-2.96	-16.27	-19.12	-0.0159	0.0021
	(0.76)	(0.37)	(2.10)	(2.14)	(10.80)	(16.20)	(0.0220)	(0.0064)
PCP retired*Post1	-4.43***	3.04***	5.20	0.31	19.92	71.19***	0.0961**	0.0441***
	(1.09)	(0.53)	(3.13)	(3.18)	(12.55)	(19.60)	(0.0309)	(0.0079)
PCP retired*Post2	-7.25***	2.92***	1.87	3.79	0.00	9.07	0.0730*	0.0127
	(1.27)	(0.57)	(3.74)	(4.22)	(12.61)	(20.36)	(0.0349)	(0.0081)
PCP retired*Lead*HPSA	2.79*	0.95	12.84***	1.29	91.47***	111.90***	0.0288	0.0268**
	(1.10)	(0.51)	(2.96)	(3.01)	(18.02)	(25.89)	(0.0300)	(0.0094)
PCP retired*Post1*HPSA	-0.28	1.98*	16.18***	-2.90	75.29***	90.22**	0.0305	0.0309*
	(1.58)	(0.84)	(4.43)	(4.13)	(22.39)	(33.39)	(0.0414)	(0.0127)
PCP retired*Post2*HPSA	-3.02	1.82*	9.99	1.08	77.18**	97.60*	-0.0489	0.0194
	(1.80)	(0.93)	(5.58)	(6.17)	(24.93)	(37.93)	(0.0493)	(0.0147)
Observations	8,651,413	8,651,413	8,651,413	8,651,413	8,651,413	8,651,413	8,651,413	8,651,413
Baseline mean	86.91	40.14	152.81	223.84	1003.60	2470.84	4.2666	1.416

Notes: The table reports estimates from equation (4). Columns (1)–(6) estimate the effects of average Medicare costs of different forms of care. Columns (7)–(8) estimate the effects on the number of medical tests. Lead refers to relative quarters -8 to -1. Post1 includes relative quarters 0 to 5, and Post2 includes the remaining quarters after PCP retirement. PCP retired = 1 if a Medicare beneficiary's initial PCP retired between 2010 and 2013. PCP retired = 0 if a Medicare beneficiary's initial PCP had not retired by 2013. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Heterogeneity Analysis: Quality of Care

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Hospitalization rates due to ACSCs				New CC		PCP value-added	
	Acute	COPD	Diabetes	Heart failure		HbA1c	Lipid	Flu Vaccination
Panel A: Solo/Group								
PCP retired*Lead	0.0001	-0.0002	-0.0002	0.0013*	0.0006	0.0006	0.0009	-0.0003
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0007)	(0.0004)	(0.0005)	(0.0003)
PCP retired*Post1	0.0001	0.0005	-0.0001	0.0017**	0.0088***	0.0032***	0.0087***	-0.0002
	(0.0002)	(0.0005)	(0.0002)	(0.0006)	(0.0009)	(0.0010)	(0.0015)	(0.0007)
PCP retired*Post2	-0.0001	0.0004	-0.0002	0.0028***	0.0029**	0.0028**	0.0091***	0.0016*
	(0.0002)	(0.0005)	(0.0002)	(0.0007)	(0.0009)	(0.0010)	(0.0016)	(0.0007)
PCP retired*Lead*Solo	0.0000	0.0001	-0.0002	-0.0016	0.0000	0.0013*	0.0001	0.0007
	(0.0003)	(0.0007)	(0.0003)	(0.0009)	(0.0013)	(0.0005)	(0.0008)	(0.0004)
PCP retired*Post1*Solo	0.0005	-0.0003	0.0000	-0.0013	0.0039*	0.0099***	0.0058	0.0053***
	(0.0004)	(0.0008)	(0.0003)	(0.0010)	(0.0018)	(0.0021)	(0.0031)	(0.0015)
PCP retired*Post2*Solo	0.0005	0.0002	-0.0003	-0.0028**	-0.0026	0.0091***	0.0050	0.0048**
	(0.0004)	(0.0008)	(0.0003)	(0.0010)	(0.0015)	(0.0020)	(0.0030)	(0.0015)
Observations	6,475,078	1,606,923	2,152,123	1,754,866	6,529,560	3,744,451	3,744,451	3,798,492
Baseline mean	0.0086	0.0101	0.0027	0.0151	0.1248	-0.0044	-0.0068	0.0041
Panel B: Whether state requires departure notice								
PCP retired*Lead	0.0000	0.0005	-0.0002	0.0012*	0.0022**	0.0009*	0.0009	0.0003
	(0.0002)	(0.0005)	(0.0002)	(0.0006)	(0.0008)	(0.0004)	(0.0006)	(0.0003)
PCP retired*Post1	0.0009***	0.0004	0.0000	0.0014*	0.0120***	0.0055***	0.0068***	0.0019*
	(0.0003)	(0.0005)	(0.0002)	(0.0007)	(0.0011)	(0.0012)	(0.0019)	(0.0009)
PCP retired*Post2	0.0001	0.0003	-0.0001	0.0017*	0.0035***	0.0047***	0.0065***	0.0034***
	(0.0003)	(0.0006)	(0.0002)	(0.0007)	(0.0010)	(0.0012)	(0.0019)	(0.0009)
PCP retired*Lead*Request	0.0001	-0.0009	-0.0002	-0.0004	-0.0021*	-0.0003	-0.0001	-0.0006
	(0.0003)	(0.0006)	(0.0002)	(0.0007)	(0.0010)	(0.0005)	(0.0007)	(0.0004)
PCP retired*Post1*Request	-0.0009**	-0.0004	-0.0003	0.0002	-0.0034*	-0.0008	0.0041	-0.0012
	(0.0003)	(0.0006)	(0.0003)	(0.0008)	(0.0013)	(0.0015)	(0.0024)	(0.0011)
PCP retired*Post2*Request	-0.0002	-0.0001	-0.0003	0.0002	-0.0022	-0.0003	0.0046	-0.0012
	(0.0003)	(0.0007)	(0.0002)	(0.0009)	(0.0012)	(0.0015)	(0.0024)	(0.0011)
Observations	8,340,920	2,131,832	2,819,519	2,320,087	8,410,946	4,827,617	4,827,617	4,895,067
Baseline mean	0.0090	0.0104	0.0029	0.0152	0.1257	-0.0047	-0.0061	0.0030
Panel C: Primary care HPSA								
PCP retired*Lead	-0.0001	-0.0006	-0.0004*	0.0010*	0.0008	0.0006	0.0006	-0.0001
	(0.0002)	(0.0004)	(0.0001)	(0.0005)	(0.0007)	(0.0003)	(0.0004)	(0.0002)
PCP retired*Post1	0.0004*	0.0001	-0.0002	0.0017***	0.0099***	0.0058***	0.0099***	0.0010
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0008)	(0.0008)	(0.0013)	(0.0006)
PCP retired*Post2	0.0000	0.0002	-0.0003	0.0017**	0.0024**	0.0049***	0.0095***	0.0026***
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0008)	(0.0008)	(0.0012)	(0.0006)
PCP retired*Lead*HPSA	0.0003	0.0014**	0.0002	-0.0001	0.0002	0.0003	0.0008	-0.0001
	(0.0003)	(0.0005)	(0.0002)	(0.0007)	(0.0009)	(0.0003)	(0.0005)	(0.0003)
PCP retired*Post1*HPSA	0.0000	0.0001	0.0003	-0.0011	-0.0001	-0.0022*	-0.0014	0.0006
	(0.0003)	(0.0006)	(0.0003)	(0.0008)	(0.0013)	(0.0010)	(0.0017)	(0.0008)
PCP retired*Post2*HPSA	0.0003	0.0010	-0.0002	0.0006	-0.0015	-0.0011	-0.0001	0.0001
	(0.0004)	(0.0007)	(0.0003)	(0.0009)	(0.0014)	(0.0010)	(0.0017)	(0.0008)
Observations	8,579,267	2,181,599	2,897,917	2,386,062	8,651,413	4,946,405	4,946,405	5,016,789
Baseline mean	0.0090	0.0103	0.0028	0.0151	0.1254	-0.0047	-0.0068	0.0031

Notes: The table reports estimates from equation (4). Lead refers to relative quarters -8 to -1. Post1 includes relative quarters 0 to 5, and Post2 includes the remaining quarters after PCP retirement. PCP retired = 1 if a Medicare beneficiary's initial PCP retired between 2010 and 2013. PCP retired = 0 if a Medicare beneficiary's initial PCP had not retired by 2013. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

with mandatory physician departure notice.[39] These findings indicate that increasing communication between retiring PCPs, their patients, and replacement PCPs is important for mitigating the cost increase associated with disruption in care. In addition, such disruption costs can also be alleviated by increasing the supply of PCPs in primary care HPSAs, although this may not necessarily improve the quality of care.[40]

7 Conclusion

The US health care system is expensive, and Medicare alone accounts for 3.6% of the GDP (CMS 2017*b*). With the population aging, health care spending will increase further. At the same time, more physicians are expected to retire in the near future, also due to aging. However, we lack evidence on the causal effects of PCP retirement on patient outcomes (Lam et al. 2020).

I use a flexible event study model that allows for potential anticipatory behavior to estimate the causal effects of PCP retirement on patient outcomes. I find that anticipatory effects are relatively small compared to post-retirement disruption effects. In addition, I only find such effects on primary care and emergency care utilization, and such changes do not have any negative impact on the quality of care during the lead period. Despite some anticipation, the major effects of PCP retirement occur after the event. Specifically, PCP retirement results in a permanent shift from primary care to specialty care and an increase in total Medicare costs by $571.62 per patient in the first 1.5 years due to the short-term increase in the utilization of emergency care, medical tests, and inpatient care. However, PCP retirement also results in better patient outcomes. Patients are more likely to be diagnosed with a chronic condition, including depression, osteoporosis, and Alzheimer's disease and related disorders. The early detection of these diseases can help patients receive more timely treatment, prolong their quality time, and potentially save on long-term formal and informal medical costs. In addition, replacement PCPs are of higher quality than retired PCPs in preventive care.

Given the estimates, a normal PCP retirement (PCPs retire at age 60 or over) incurs about a

[39] PCPs in states with mandatory physician departure notice are also required to inform patients how to ensure smooth transfer of their medical records.

[40] Physicians respond to financial incentives (Clemens and Gottlieb 2014; Brekke et al. 2017). The Lewin Group (2015) and Khoury et al. (2021) have shown that both the Medicare bonus payment to physicians in shortage areas and the Primary Care Incentive Payment Program are effective at increasing the labor supply of PCPs.

$57,200 increase in total Medicare costs for the Original Medicare elderly beneficiaries, as a retired PCP on average has 20 dependent patients in the 20% Medicare sample.[41,42] With one third of the 228,100 active PCPs in 2018 expected to retire in the coming decade due to aging, the projected Original Medicare costs due to PCP retirement would be at least $4.3 billion (in 2010 USD) from 2018 to 2028.[43] Some of the increase in medical costs can be paid back through the long-term savings from early detection of chronic conditions. Some of the increase in costs, however, will need to be mitigated through relevant policies. First, solo practitioners should make more effort to help their patients smoothly transfer to another PCP. Second, making physician departure notice mandatory at the state level is a useful policy to contain the increase in medical costs and prevent negative impacts on the quality of care. Almost half of states have not adopted this policy and should consider implementing it. Third, increasing PCPs in primary care HPSAs can help to mitigate the increase in medical costs due to PCP retirement.

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[41]This estimate is the lower bound of the costs of PCP retirement, because it does not capture the costs to Medicare Advantage patients, private insured patients, or uninsured patients, and it only includes Medicare payments. In addition, this estimate is derived from the matched sample in which patients are healthier and richer than the general Original Medicare population and are less affected by PCP retirements.

[42]Appendix C shows the results from early retirement as well. Compared to normal PCP retirements, early retirements are associated with worse patient outcomes and especially a larger and persistent increase in medical costs.

[43]This calculation is regardless of other potential changes, such as the increase in the share of PCPs working in a group practice (Welch et al. 2013; Muhlestein and Smith 2016) and the projected increase in PCP shortage (Association of American Medical Colleges 2020). As the heterogeneity analyses show, the former would mitigate the increase in costs, whereas the latter would exacerbate the increase in costs.

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Appendix A Additional Figures and Tables

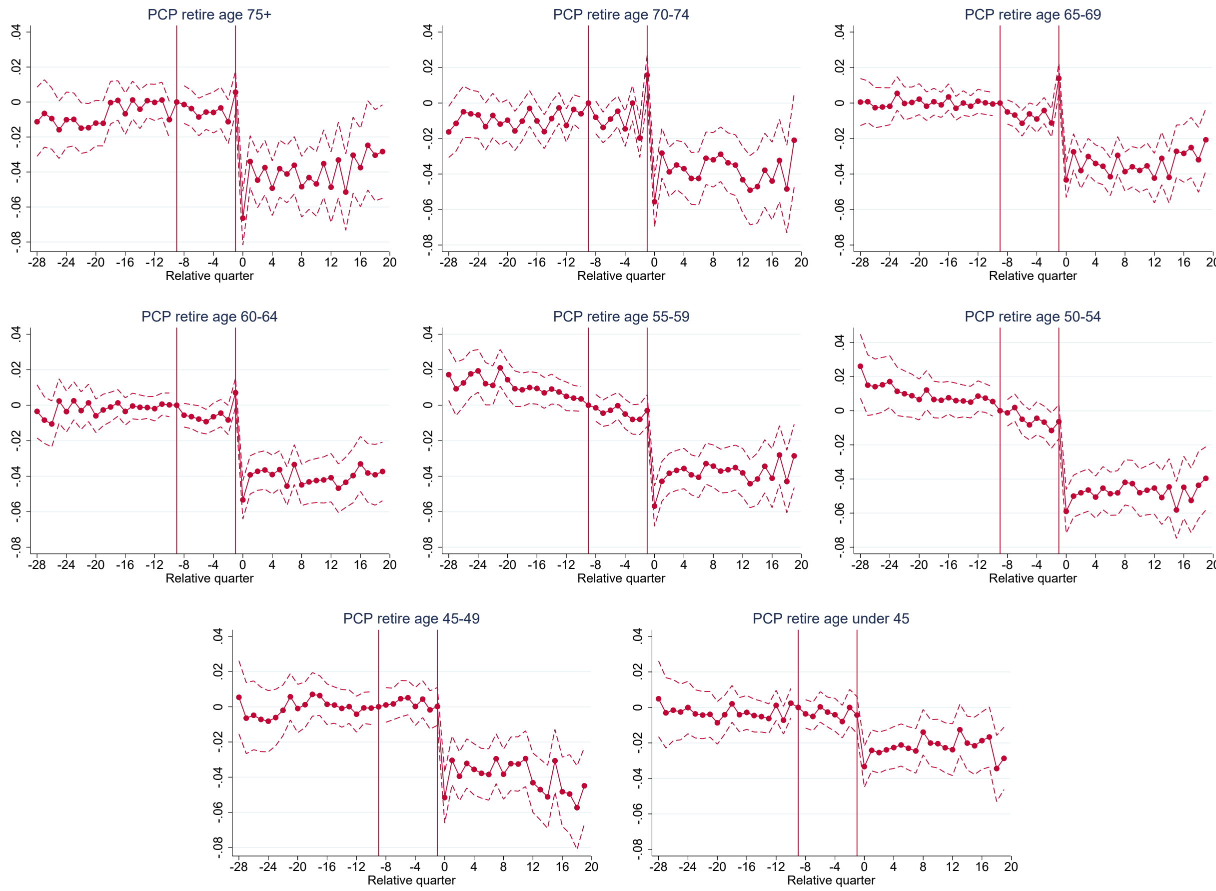


Figure A1: Changes in Having Any PCP Visit by PCP Retirement Age

Notes: Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval.

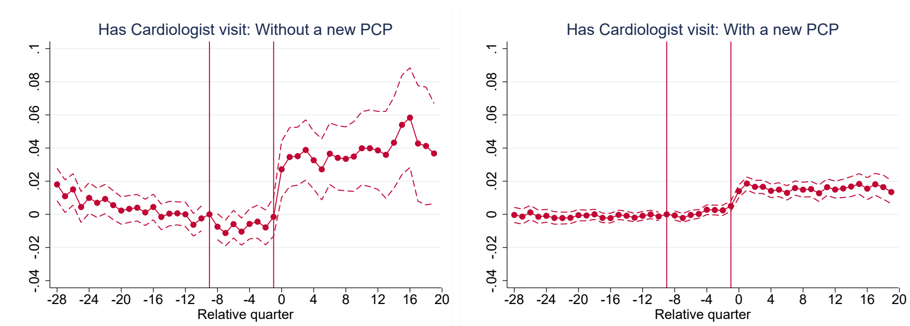


Figure A2: Cardiologist Visit by Whether a Patient Finds a New PCP

Notes: Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval.

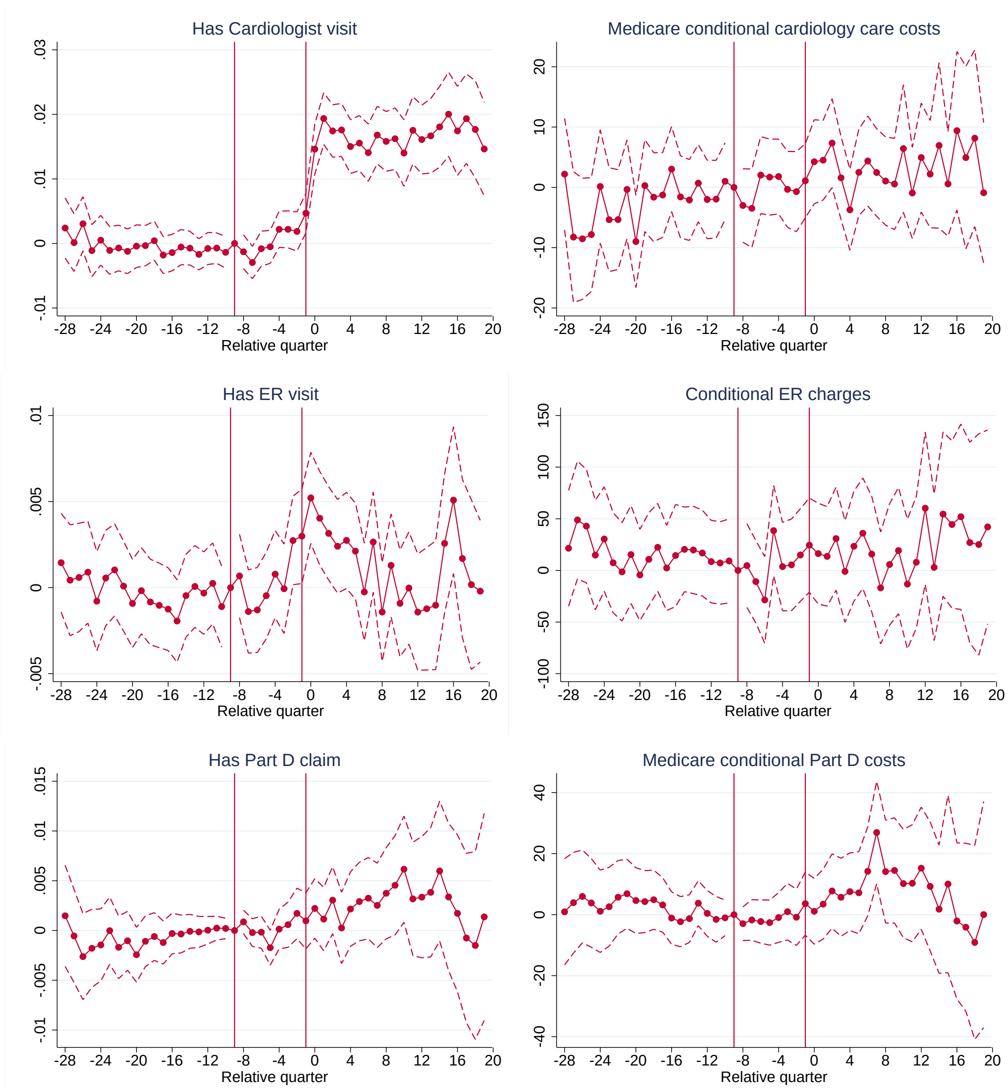


Figure A3: Effects on Other Health Care Utilization: Extensive and Intensive Margins

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

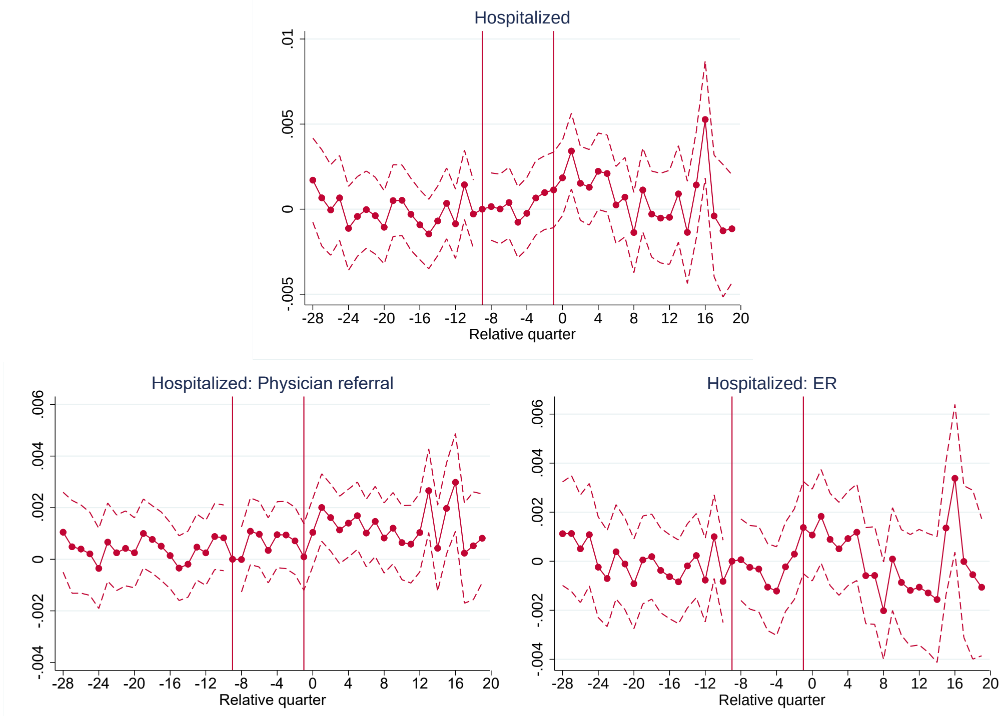


Figure A4: Effect of PCP Retirement on Hospitalization

Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. A patient can have both inpatient admissions due to physician referral and through ER in a same quarter.

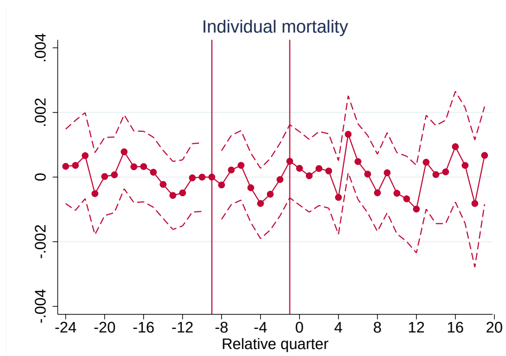
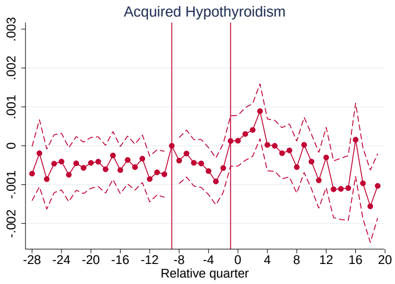
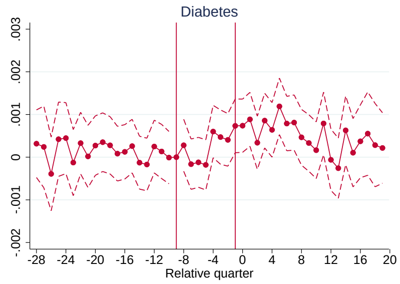


Figure A5: Effect of PCP Retirement on Individual Mortality

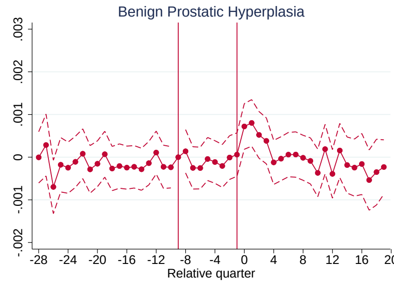
Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Since I keep individuals with at least one complete year of data, patients “can” only die from their second observed year onward. Therefore, the analysis time period is one year shorter than for the other analyses.



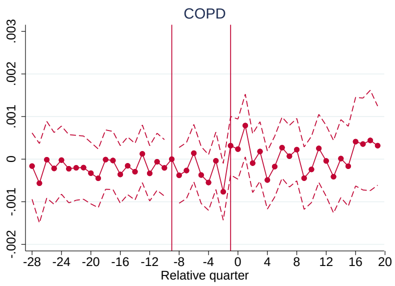
(a) Baseline mean = 0.0056



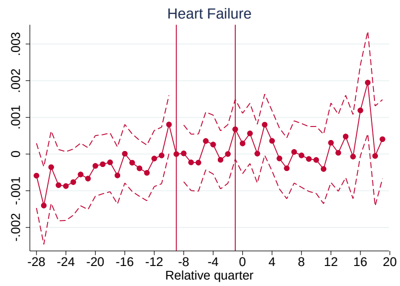
(b) Baseline mean = 0.0073



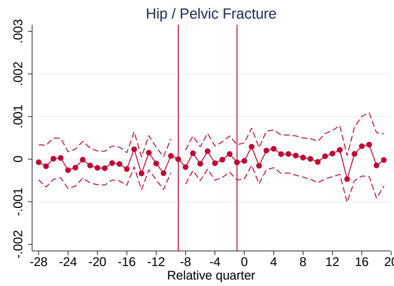
(c) Baseline mean = 0.0043



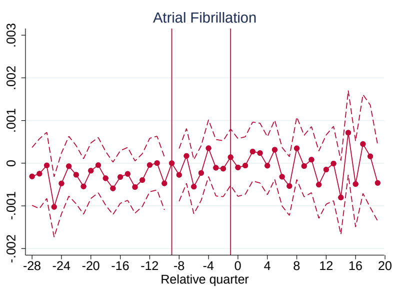
(d) Baseline mean = 0.0076



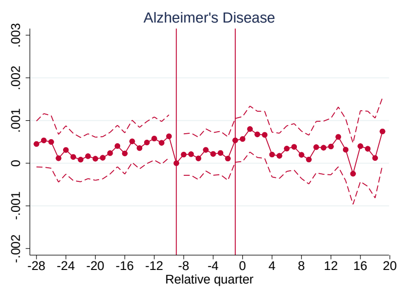
(e) Baseline mean = 0.0097



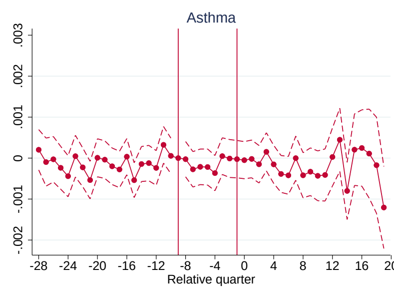
(f) Baseline mean = 0.0024



(g) Baseline mean = 0.0059



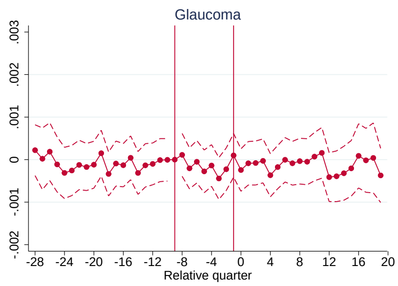
(h) Baseline mean = 0.0039



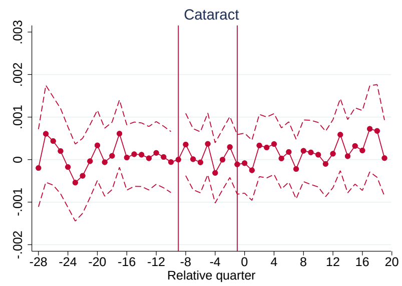
(i) Baseline mean = 0.0031

Figure A6: Diagnosed with a New Chronic Disease – Moderate Effect

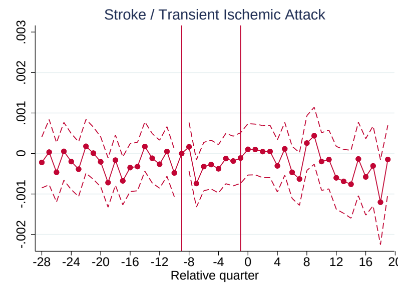
Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9.



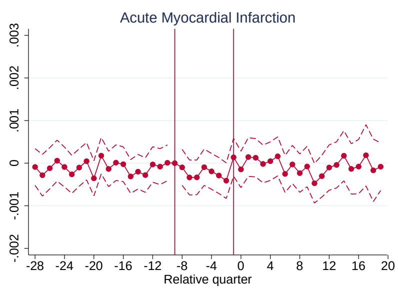
(a) Baseline mean = 0.0044



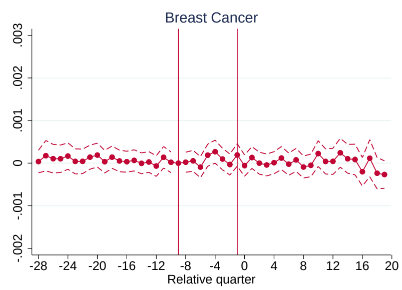
(b) Baseline mean = 0.0105



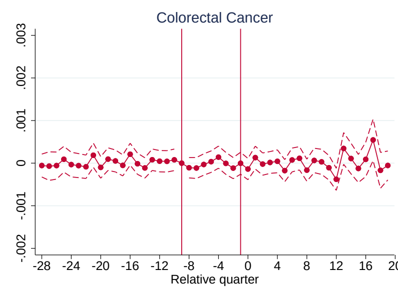
(c) Baseline mean = 0.0056



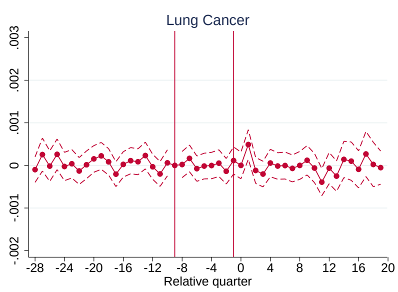
(d) Baseline mean = 0.0025



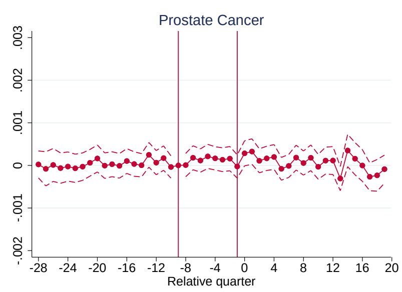
(e) Baseline mean = 0.0011



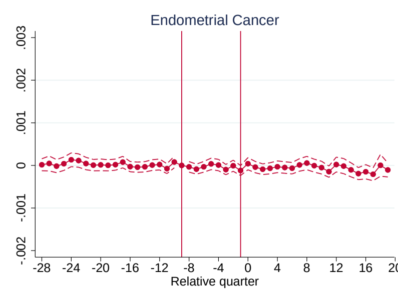
(f) Baseline mean = 0.0011



(g) Baseline mean = 0.0014



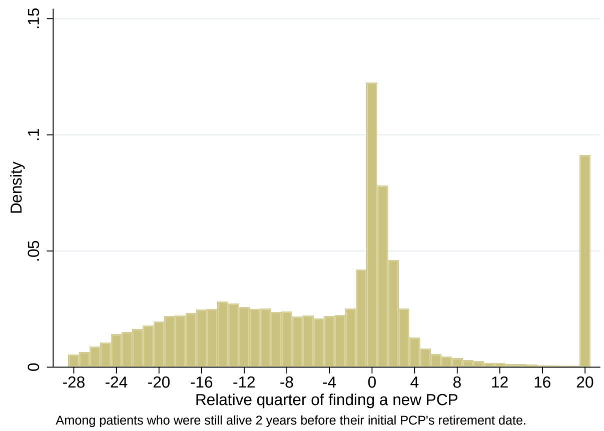
(h) Baseline mean = 0.0014



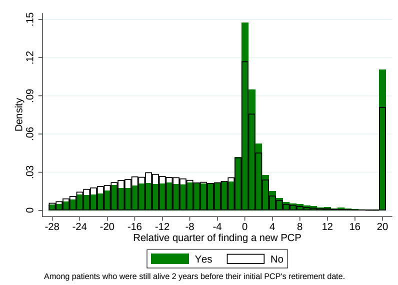
(i) Baseline mean = 0.0003

Figure A7: Diagnosed with a New Chronic Disease – No Effect

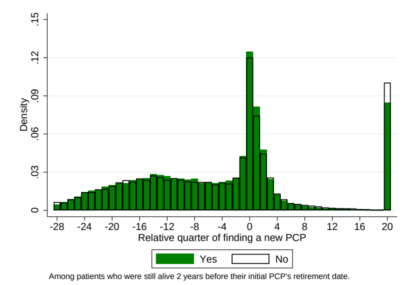
Notes: Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9.



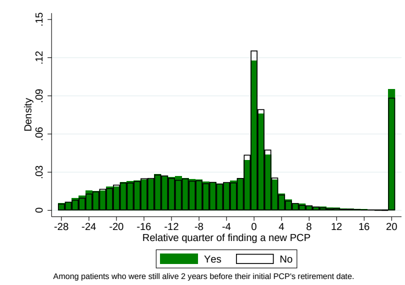
(a) Matched sample 1



(b) Whether a solo PCP



(c) Whether PCP departure notice



(d) Whether a primary care HPSA

Figure A8: Time Elapsed Before Finding a New PCP

Note: These histograms only keep patients who were still alive when entering the lead period of PCP retirement (two years before PCP retirement). Relative quarter 20 includes patients who had not find a replacement PCP by the 20th relative quarter after PCP retirement, either due to no new accountable PCP being identified or due to death.

Table A1: Sample Composition

	(1) Aged 65+	(2) Original Medi-care	(3) Full part A & B	(4) Non-movers	(5) Has ≥ 1 PCP	(6) Initial PCP in 2006/2007
Individual characteristics						
Age in 2006	74.59	75.24	75.73	75.71	75.60	76.04
Share male	0.43	0.43	0.42	0.42	0.42	0.41
Share white	0.86	0.88	0.90	0.89	0.89	0.90
Share black	0.08	0.07	0.06	0.07	0.07	0.06
Share dually eligible (FY)	0.12	0.11	0.11	0.11	0.11	0.12
Share disabled (FY)	0.08	0.08	0.08	0.08	0.08	0.08
No. of chronic conditions (FY)	2.60	3.18	3.48	3.49	3.59	3.84
HCC score (FY)				0.99	1.00	1.04
Share of non-MD PCPs					0.07	0.06
ZIP code-level characteristics						
Mean household income	70,334	71,301	70,796	70,352	70,714	70,823
Median household income	56,109	56,635	56,242	55,915	56,215	56,358
Population	26,583	25,010	24,509	24,435	24,667	24,900
Share rural	0.22	0.25	0.26	0.26	0.25	0.25
Share white	0.68	0.71	0.72	0.72	0.72	0.72
Share elderly	0.15	0.16	0.16	0.16	0.16	0.16
Share house vacant	0.11	0.11	0.12	0.11	0.11	0.11
N	7,717,259	4,846,198	4,313,429	3,730,750	3,564,158	3,114,321
Percent of sample (column [2])		100%	89.01%	76.98%	73.55%	64.26%

Note. Each column adds an additional restriction to the 20% Medicare patient sample. Column (1) includes all elderly Medicare beneficiaries. Column (2) keeps patients who are enrolled in Original/fee-for-service Medicare throughout the entire sample period, and column (3) includes patients who have full coverage of both Part A and Part B throughout the entire sample period. Column (4) further restricts the sample to non-movers, who live in the same HSA throughout the entire sample period. Column (5) restricts the sample to those who had an identifiable accountable PCP at any point during the sample period, and column (6) restricts the sample to those who had an accountable PCP from the beginning of the sample period, i.e., 2006 or 2007. The treatment and control groups are constructed from this sample. (FY) indicates a patient's first-observed year in the Medicare claims. The HCC risk score is calculated based on patients' demographic characteristics and diagnoses.

Table A2: Means and Standard Deviations of PCP Value-added

	General analysis sample			Matched analysis sample		
	(1) Potential treatment group (PCP retired 2010–2013)	(2) Treatment group (PCP retired 60+)	(3) Control group (PCP did not retire by 2013)	(4) Matched treatment group	(5) Matched control group	(6) Difference (p-value)
PCP value-added:						
HbA1c test	-0.0055	-0.0079	-0.0003	-0.0067	-0.0076	0.00
(SD)	(0.0379)	(0.0406)	(0.0974)	(0.0403)	(0.0955)	
Lipid test	-0.0151	-0.0180	-0.0019	-0.0150	-0.0148	0.65
(SD)	(0.0765)	(0.0808)	(0.0823)	(0.0796)	(0.0880)	
Flu vaccination	-0.0047	-0.0028	0.0026	-0.0020	-0.0009	0.00
(SD)	(0.0352)	(0.0372)	(0.0447)	(0.0371)	(0.0467)	
N	293,665	169,270	2,468,502	143,271	143,271	

Notes: (SD) represents the standard deviations of PCP value-added measures in each patient sample. N is the number of patients in each analysis sample.

Table A3: PCP Adherence ("Value-added") and Other Characteristics

	(1) HbA1c test	(2) Lipid test	(3) Flu vaccination
Board-certified	0.0010**	-0.0002	0.0038***
	(0.0003)	(0.0005)	(0.0002)
Medical school ranking (1-100)	-0.0001***	0.0001***	-0.0001***
	(0.0000)	(0.0000)	(0.0000)
PCP has MD/DO	0.0032***	0.0205***	0.0068***
	(0.0004)	(0.0006)	(0.0003)
PCP age (2010)	0.0013***	0.0009***	0.0009***
	(0.0001)	(0.0002)	(0.0001)
PCP age^2	-0.0000***	-0.0000***	-0.0000***
	(0.0000)	(0.0000)	(0.0000)
Observations	130,405	130,405	146,740
R^2	0.0102	0.0145	0.0274
Mean	-0.0009	-0.0062	-0.0043

Notes. All accountable PCPs are kept for analysis, including those who retired in any year during 2006–2015 and those who had not retired by 2015. The number of observations is lower in columns (1) and (2), because some PCPs may not have diabetes patients to calculate their PCP value-added on diabetes management. Medical school ranking is obtained from the US News Best Medical Schools: Primary Care (ranked in 2019). Ranks 1 through 90 are taken directly from the ranking. For the rest and missing medical schools, 100 is assigned. Since I use a broad definition of PCP, MD/DO is compared relative to non-physician practitioners, such as nurse practitioners and physician assistants.

Table A4: PCP Retirement Timing and Case Burden

	(1)	(2)
	PCP retirement quarter	
HCC risk score 2007 Q1	0.1131	0.3620
	(0.1830)	(0.2644)
HCC risk score 2007 Q2	-0.22	-0.0942
	(0.2029)	(0.2981)
HCC risk score 2007 Q3	0.2232	0.1452
	(0.2025)	(0.3045)
HCC risk score 2007 Q4	0.1105	-0.2815
	(0.2184)	(0.3216)
HCC risk score 2008 Q1	-0.2087	-0.0482
	(0.1791)	(0.2692)
HCC risk score 2008 Q2	0.2123	0.0961
	(0.2085)	(0.2933)
HCC risk score 2008 Q3	-0.0870	0.2267
	(0.2015)	(0.2973)
HCC risk score 2008 Q4	-0.0617	0.0532
	(0.2111)	(0.3112)
HCC risk score 2009 Q1	-0.0706	-0.2709
	(0.1890)	(0.2557)
HCC risk score 2009 Q2	0.2135	-0.0879
	(0.1958)	(0.2730)
HCC risk score 2009 Q3	-0.3151	-0.1930
	(0.1937)	(0.2692)
HCC risk score 2009 Q4	-0.1942	0.0270
	(0.1979)	(0.2690)
Average cost 2007 Q1	-0.0019	-0.0066*
	(0.0020)	(0.0029)
Average cost 2007 Q2	-0.0010	0.0026
	(0.0022)	(0.0031)
Average cost 2007 Q3	-0.0039	-0.0041
	(0.0025)	(0.0034)
Average cost 2007 Q4	0.0021	0.0013
	(0.0026)	(0.0036)
Average cost 2008 Q1	-0.0015	0.0005
	(0.0023)	(0.0032)
Average cost 2008 Q2	0.0015	0.0028
	(0.0022)	(0.0029)
Average cost 2008 Q3	0.0001	-0.0063
	(0.0024)	(0.0033)
Average cost 2008 Q4	0.0044	0.0080*
	(0.0024)	(0.0032)
Average cost 2009 Q1	-0.0029	-0.0013
	(0.0023)	(0.0031)
Average cost 2009 Q2	-0.0035	-0.0030
	(0.0031)	(0.0040)
Average cost 2009 Q3	0.0015	-0.0008
	(0.0030)	(0.0039)
Average cost 2009 Q4	0.0016	0.0005
	(0.0024)	(0.0032)

Observations	5,668	5,668
Adjusted R^2	0.0034	0.0043
Weighted	No	Yes

Notes. PCPs who retired at age 60 or above between 2010 and 2013 are kept for analysis. Case burden is measured by the average patients' HCC risk score and average per-visit Medicare cost of a PCP's patient pool (including all patients who visit the PCP in that quarter) in each quarter. Weight is the average number of patient visits per quarter in the pre-retirement period. *** p<0.01, ** p<0.05, *** p<0.1.

Table A5: Effect of PCP Retirement on Hospitalization

	Hospitalized	Through referral	Through ER
PCP retired*Lead-period	0.0004	0.0003	-0.0001
	(0.0004)	(0.0003)	(0.0004)
PCP retired*Post-period 1	0.0022***	0.0011***	0.0012*
	(0.0005)	(0.0003)	(0.0005)
PCP retired*Post-period 2	0.0003	0.0008*	-0.0006
	(0.0006)	(0.0003)	(0.0005)
Observations	8,665,305	8,665,305	8,665,305
R^2	0.10	0.05	0.10
Baseline mean	0.0761	0.0296	0.0499

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A6: Robustness Checks: Health Care Utilization

	(1) Primary care	(2) Cardiology	(3) ER	(4) Drug	(5) Inpatient	(6) Total costs	(7) Diagnostic tests	(8) Imaging tests
Panel A: Matched sample 2								
PCP retired*Lead-period	-1.15	0.41	1.22	-2.38	14.85	17.65	0.0016	0.0150**
	(0.71)	(0.32)	(1.85)	(1.85)	(9.85)	(14.51)	(0.0194)	(0.0055)
PCP retired*Post-period 1	-4.79***	3.69***	9.21**	-0.56	42.04***	98.21***	0.1181***	0.0588***
	(1.05)	(0.50)	(2.88)	(2.92)	(11.97)	(18.48)	(0.0290)	(0.0073)
PCP retired*Post-period 2	-7.60***	3.24***	4.78	3.93	15.20	33.61	0.0888*	0.0251**
	(1.23)	(0.58)	(3.76)	(4.12)	(12.83)	(20.52)	(0.0350)	(0.0081)
Observations	8,222,228	8,222,228	8,222,228	8,222,228	8,222,228	8,222,228	8,222,228	8,222,228
R^2	0.24	0.12	0.12	0.43	0.08	0.13	0.36	0.13
Baseline mean	87.57	40.23	152.85	222.71	1003.22	2463.94	4.2922	1.4178
Panel B: Treatment group only								
PCP retired*Lead-period	-1.06	-0.07	2.89	0.37	45.00***	57.78***	0.0007	0.0154*
	(0.72)	(0.35)	(1.78)	(1.85)	(12.24)	(17.48)	(0.0192)	(0.0067)
PCP retired*Post-period 1	-6.37***	3.61***	11.34***	3.46	88.25***	153.11***	0.1206***	0.0600***
	(1.30)	(0.66)	(3.21)	(3.51)	(18.56)	(27.12)	(0.0355)	(0.0108)
PCP retired*Post-period 2	-11.98***	3.64***	8.30	9.90*	79.43**	114.04**	0.0919	0.0309*
	(1.87)	(0.95)	(5.10)	(4.86)	(24.90)	(36.66)	(0.0518)	(0.0148)
Observations	5,076,856	5,076,856	5,076,856	5,076,856	5,076,856	5,076,856	5,076,856	5,076,856
R^2	0.25	0.11	0.12	0.44	0.08	0.14	0.36	0.13
Baseline mean	84.97	38.94	155.97	233.99	1002.08	2475.04	4.1237	1.4020

Notes: The table reports DID estimates from equation (2). Columns (1)–(6) estimate the effects of average Medicare costs of different forms of care. Columns (7)–(8) estimate the effects on the number of medical tests. Lead-period refers to relative quarters -8 to -1. Post-period 1 includes relative quarters 0 to 5, and Post-period 2 includes the remaining quarters after PCP retirement. PCP retired = 1 if a Medicare beneficiary's initial PCP retired between 2010 and 2013. For matched sample 2, PCP retired = 0 if a Medicare beneficiary's initial PCP had not retired by quarter 4 of 2015. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A7: Effect of PCP Retirement on Individual Mortality

	Linear probability model	Cox prop. hazard model
PCP retired*Lead-period	-0.0001	-0.0070
	(0.0002)	(0.0118)
PCP retired*Post-period 1	0.0002	0.0121
	(0.0002)	(0.0138)
PCP retired*Post-period 2	-0.0001	-0.0038
	(0.0002)	(0.0141)
PCP retired	0.0001	0.0027
	(0.0002)	(0.0093)
Observations	7,446,877	7,446,877
R^2	0.01	
Baseline mean	0.0175	

Notes: The table reports DID estimates from equation (2) and the hazard model in equation (3). Lead-period refers to relative quarters -8 to -1; Post-period 1 includes relative quarters 0 to 5; and Post-period 2 includes the remaining quarters after PCP retirement. Since I keep individuals with at least one complete year of data, patients "can" only die from their second observed year onward. Therefore, the analysis time period is one year shorter than for the other analyses. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A8: Robustness Checks: Quality of Care

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Hospitalization rates due to ACSCs				New CC	PCP value-added		
	Acute	COPD	Diabetes	Heart failure		HbA1c	Lipid	Flu vaccination
Panel A: Matched sample 2								
PCP retired*Lead-period	0.0000	0.0000	-0.0003*	0.0005	0.0015**	0.0008**	0.0010*	-0.0001
	(0.0001)	(0.0003)	(0.0001)	(0.0004)	(0.0006)	(0.0003)	(0.0004)	(0.0002)
PCP retired*Post-period 1	0.0004*	0.0005	-0.0001	0.0010*	0.0105***	0.0055***	0.0097***	0.0010
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0007)	(0.0008)	(0.0012)	(0.0005)
PCP retired*Post-period 2	0.0002	0.0008	-0.0002	0.0013*	0.0032***	0.0052***	0.0097***	0.0025***
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0008)	(0.0008)	(0.0012)	(0.0006)
Observations	8,153,416	2,079,342	2,765,491	2,263,579	8,222,228	4,729,277	4,729,277	4,793,375
R^2	0.05	0.08	0.04	0.09	0.02	0.85	0.81	0.82
Baseline mean	0.0089	0.0105	0.0029	0.0150	0.1259	-0.0048	-0.0065	0.0032
Panel B: Treatment group only								
PCP retired*Lead-period	0.0001	0.0002	-0.0002	0.0012*	0.0015*	0.0003	0.0005	-0.0004**
	(0.0002)	(0.0004)	(0.0002)	(0.0005)	(0.0007)	(0.0002)	(0.0003)	(0.0002)
PCP retired*Post-period 1	0.0006*	0.0005	-0.0001	0.0021**	0.0113***	0.0045***	0.0094***	0.0012**
	(0.0003)	(0.0006)	(0.0002)	(0.0007)	(0.0011)	(0.0006)	(0.0011)	(0.0005)
PCP retired*Post-period 2	0.0005	0.0004	-0.0003	0.0029**	0.0052***	0.0027**	0.0088***	0.0033***
	(0.0004)	(0.0008)	(0.0003)	(0.0009)	(0.0014)	(0.0009)	(0.0016)	(0.0007)
Observations	5,035,983	1,285,424	1,707,220	1,402,353	5,076,856	2,783,352	2,783,352	2,837,298
R^2	0.05	0.08	0.04	0.09	0.02	0.66	0.72	0.72
Baseline mean	0.0090	0.0103	0.0030	0.0151	0.1257	-0.0058	-0.0097	0.0018

Notes: The table reports DID estimates from equation (2). Lead-period refers to relative quarters -8 to -1. Post-period 1 includes relative quarters 0 to 5, and Post-period 2 includes the remaining quarters after PCP retirement. PCP retired = 1 if a Medicare beneficiary's initial PCP retired between 2010 and 2013. For matched sample 2, PCP retired = 0 if a Medicare beneficiary's initial PCP had not retired by quarter 4 of 2015. For avoidable hospitalizations, only observations before October 1, 2015 are included in the analyses due to the switch from ICD-9 to ICD-10 code in October 2015. For chronic ACSCs, only data from calendar year $t + 1$ are included in the analyses after patients were first diagnosed with a chronic condition in year t. For PCP quality, only relative quarters with at least one visit to a beneficiary's accountable PCP are kept for analysis. Baseline mean is the mean of the dependent variable in relative quarters $\leq$ -9. Standard errors are clustered at the initial accountable PCP level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A9: State Requirement on Physician Departure Notice

State	Mandatory	Recommended	Number of days
Alabama	No	Yes	
Alaska	No	Yes	
Arizona	Yes		90
Arkansas	No	Yes	
California	No	Yes	
Colorado	Yes		
Connecticut	Yes		14
Delaware	Yes		30
District of Columbia	Yes		
Florida	Yes		30
Georgia	Yes		30
Hawaii	N/A		
Idaho	N/A		
Illinois	Yes		30
Indiana	Yes		60--90
Iowa	Yes		30
Kansas	Yes		
Kentucky	No	Yes	
Louisiana	No	Yes	
Maine	No	Yes	90
Maryland	Yes		
Massachusetts	No	Yes	30
Michigan	No	Yes	30
Minnesota	No	No	0
Mississippi	Yes		30
Missouri	No	Yes	30
Montana	No	No	
Nebraska	N/A		
Nevada	Yes		
New Hampshire	Yes		30
New Jersey	Yes		30
New Mexico	Yes		30
New York	No	No	
North Carolina	No	Yes	30
North Dakota	Yes		
Ohio	Yes		30
Oklahoma	No	Yes	
Oregon	No	No	
Pennsylvania	Yes		30
Rhode Island	Yes		90
South Carolina	Yes		90
South Dakota	N/A		
Tennessee	Yes		30
Texas	Yes		30
Utah	N/A		
Vermont	No	Yes	30
Virginia	Yes		
Washington	Yes		30
West Virginia	No	Yes	30
Wisconsin	Yes		
Wyoming	Yes		30

Notes: Information is collected from three sources: (1) relevant state statutes, (2) current information from the state medical board, and (3) historical guidelines (in PDF format) from the state medical board or medical association/society. Number of days is how many days before their departure physicians need to notify patients. N/A represents no information is found for a state.

Table A10: Summary Statistics of the Samples in Heterogeneity Analyses

	(1) Solo practice	(2) Group practice	(3) Departure notice required	(4) Departure notice not required	(5) Primary care HPSA	(6) Partial or non-HPSA
Individual characteristics						
Age in 2006	76.29	76.06	76.14	76.28	76.27	76.14
Share male	0.42	0.43	0.42	0.42	0.42	0.42
Share white	0.90	0.94	0.93	0.92	0.90	0.94
Share black	0.06	0.05	0.06	0.05	0.07	0.04
Share dually eligible (FY)	0.11	0.07	0.08	0.11	0.10	0.08
Share disabled (FY)	0.08	0.07	0.07	0.08	0.08	0.07
No. of chronic conditions (FY)	3.88	3.55	3.72	3.71	3.76	3.68
HCC score (FY)	1.04	0.98	1.01	1.02	1.03	1.00
Share of non-MD PCPs	0.02	0.03	0.03	0.02	0.03	0.02
Neighborhood characteristics						
Mean household income	74,116	70,604	71,324	73,203	70,564	72,713
Median household income	59,280	56,097	57,155	57,375	55,379	58,237
Population	26,910	24,218	24,741	24,924	26,674	23,651
Share rural	0.20	0.26	0.23	0.26	0.23	0.25
Share white	0.68	0.74	0.73	0.73	0.68	0.76
Share elderly	0.16	0.15	0.16	0.15	0.15	0.16
Share house vacant	0.10	0.11	0.11	0.11	0.11	0.10
Share HPSA	0.41	0.39	0.39	0.41	–	–
Initial PCP characteristics						
PCP age in 2011	68.12	66.26	66.61	66.96	66.86	66.60
No. of unique patients (2008)	307	371	371	350	345	371
Share solo practice (pure)	–	–	0.23	0.33	0.27	0.26
Share group practice (pure)	–	–	0.57	0.46	0.53	0.53
Share mandatory departure notice	0.53	0.65	–	–	0.58	0.61
PCP "value-added":						
Hemoglobin A1c test	-0.0171	-0.0028	-0.0053	-0.0084	-0.0059	-0.0072
Lipid test	-0.0170	-0.0146	-0.0145	-0.0141	-0.0123	-0.0167
Flu vaccination	-0.0090	0.0022	-0.0010	-0.0035	-0.0040	-0.0007
N	28,380	79,762	83,404	55,786	55,740	87,320

Notes: This table shows the summary statistics of the matched treatment group (column [4] in Table 1) used in three heterogeneity analyses. Due to sample construction, the summary statistics of the matched control group are similar. Variable definitions are the same as in Table 1. N represents the number of patients in each subgroup.

Appendix B Construction of Variables

Primary care practitioners (PCPs) and specialists are identified using the Line CMS Provider Specialty Code from the Carrier Claims File. **PCPs** include the following specialties: General Practice (01), Family Practice (08), Internal Medicine (11), Geriatric Medicine (38), Clinical Nurse Specialist (89), Nurse Practitioner (50), and Physician Assistant (97) (CMS 2017*a*); the **Cardiologist** code is 06.

Primary care services are identified using Healthcare Common Procedure Coding System (HCPCS) codes, including evaluation and management services provided in office and other non-inpatient and non-emergency-room settings, as well as initial Medicare visits and annual wellness visits (CMS 2017*a*).

Accountable PCP is defined as the PCP who accounted for a larger share of allowed charges for primary care services for the beneficiary than other PCPs in a given year. If two PCPs tie for the largest share of allowed charges, then the numbers of patient primary care visits are compared. If two PCPs still tie, then the beneficiary is assigned to the PCP who provided primary care services most recently (CMS 2017*a*).

For PCP visits and cardiologist visits, I only consider visits in **outpatient settings**, which include a physician's office, hospital outpatient facility, federally qualified health center and rural health clinic, as defined by Dartmouth Atlas 2018.[44]

ER utilization is identified based on the revenue center codes and ER charge amounts from claims.[45] In outpatient claim files, ResDAC identifies revenue center codes 0400-0459 and 0981 as indicating ER services. Since I am using MedPAR files, inpatient ER visits are identified using MedPAR Emergency Room Charge Amount. My ER visits are the sum of outpatient ER visits and inpatient ER visits.

Diagnostic and imaging tests are based on Berenson–Eggers Type of Service (BETOS) codes (Song et al. 2010) in the Carrier Line File: codes beginning with T are diagnostic tests, and codes beginning with I are imaging procedures.

Avoidable hospitalizations due to ambulatory care sensitive conditions (ACSCs) are identified using the principal diagnosis code (ICD-9) for hospital admissions. Hospitalizations are

[44] http://www.dartmouthatlas.org/data/table.aspx?ind=170

[45] https://resdac.org/articles/how-identify-hospital-claims-emergency-room-visits-medicare

excluded if they meet any of the two conditions: (1) the hospital admission is a transfer from a hospital, skilled nursing facility, intermediate care facility, or other health care facility; or (2) the hospitalization is missing a principal diagnosis. In addition, hospitalizations involving certain diagnosis codes that are not preventable are excluded.[46]

The 27 **chronic conditions** are identified from the Master Beneficiary Summary File (MBSF): Chronic Conditions Segment, which follows the CMS Chronic Conditions Data Warehouse (CCW) algorithms. The data record the first date a beneficiary is diagnosed with a specific chronic condition, and the number of chronic conditions an individual has in the middle and at the end of each year.

Preventive procedures are identified from the CPT/HCPCS codes, following the rules used by the Dartmouth Atlas and the CMS. The details are in https://www.dartmouthatlas.org/interactive-apps/quality-effective-care/ and https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/qr_immun_bill.pdf.

Several patient characteristic variables are from the Medicare Beneficiary Summary File (MBSF). **Dual eligibility** equals 1 in year t if the number of state buy-in months is at least one in this year. **Disability** equals 1 if an individual's original entitlement or current entitlement code is not 0, i.e., 1. Disability Insurance Benefits (DIB), 2. End-stage Renal Disease (ESRD) or 3. Both DIB and ESRD.

Hierarchical Condition Category (HCC) risk scores are calculated using the CMS software: https://www.cms.gov/medicare/health-plans/medicareadvtgspecratestats/risk-adjustors.html

I derive **PCP quality measures** from the claim data based on each PCP's patient pool, because in this way I can obtain complete and comparable quality measures for all of the PCPs in my sample.[47] I follow the empirical strategy in Chetty et al. (2014), a generalized model that extends the classical teacher value-added (contribution) on test scores (Kane and Staiger 2008). This approach allows for drift in PCP quality over time to estimate a PCP's adherence (contribution) to three

[46] The details can be found here: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/PhysicianFeedbackProgram/Downloads/2014-ACSC-MIF.pdf

[47] MPIER has information on practitioners' medical school attended and whether they are board-certified, but it does not include PCPs entering Medicare after the second quarter in 2007.

recommended preventive procedures: annual HbA1c test for diabetics, annual blood lipid test for diabetics, and annual flu vaccination (Baicker and Chandra 2004). I use these three recommended preventive procedures instead of patients' health status – a counterpart of students' test scores – because it is hard to attribute a patient's health status to a PCP.[48] By contrast, these preventive procedures have been proven by the medical guidelines to be clinically efficient, and the existing literature relies on them to evaluate a PCP's performance (Goodman et al. 2010).

To summarize, the idea is to treat PCPs' adherence to these recommended preventive procedures as a residual component and allow for drift over time. When estimating a PCP's adherence to a recommended preventive procedure in calendar year t, it is the best linear predictor based on this PCP's residuals in other years.

Since we want to know a PCP's contribution to whether patients receive a recommended procedure p (subscript omitted) in year t: P^*_{it}, equation (B1) illustrates how the PCP component affects P^*_{it}, where μ_{jt} is PCP j's contribution on a recommended procedure in year t and is my key variable of interest.[49]

$$P^*_{it} = \beta \cdot X_{it} + \mu_{jt} + \varepsilon_{it} \tag{B1}$$

We can rewrite equation (B1) as the following, and we can estimate μ_{jt} by first obtaining the residual from equation (B2):

$$P_{it} = P^*_{it} - \beta \cdot X_{it} = \mu_{jt} + \varepsilon_{it}, \tag{B2}$$

where β is estimated by adding physician fixed effects α_j in equation (B3), i.e., using within-PCP variation:

$$P^*_{it} = \alpha_j + \beta \cdot X_{it} + \sigma_{it}, \tag{B3}$$

where X_{it} includes patient i's five-year age bin, race, gender, HRR, and lagged same procedure use in year $t-1$ following Kane and Staiger (2008) and Chetty et al. (2014).[50]

[48]Fletcher et al. (2014) estimate the "value-added" of attending physicians, where they use the changes in patients' health status during the course of a hospitalization as the counterpart for students' test scores.

[49]A key difference between Chetty et al. (2014)'s measure and the previous measure of teacher value-added is that they allow for drift in value-added. Following their approach, I use data from other years (not t) to predict a PCP's μ_{jt}, which can avoid confounding factors that simultaneously affect a PCP's contribution and patients' preventive procedure use in the same year.

[50]A concern with estimating PCP contribution is that patients may sort into PCPs based on their own characteristics.

After obtaining the residuals P_{it} from (B2) for each year, I take the average across patients with the same PCP j, i.e., $\bar{P}_{jt} = \frac{1}{\#\ of\ i} \sum_i P_{it}$. Since the idea is to use residuals from other years to predict a PCP's adherence in year t, the next step is to solve for weights $\vec{\phi}$, which makes the PCP's adherence in year t the best linear predictor of P_{it} based on $P_{i,s \neq t}$:

$$\vec{\phi} = \underset{\{\phi_1, \ldots \phi_{t-1}, \phi_{t+1}, \ldots \phi_T\}}{\operatorname{argmin}} \sum_j (\overline{P}_{jt} - \sum_{s \neq t} \phi_s \overline{P}_{js})^2 \tag{B4}$$

Finally, after solving for optimal weights $\vec{\phi}$, PCP adherence in year t is given by:

$$\hat{\mu}_{jt} = \sum_{s \neq t} \phi_s \overline{P}_{js} = \vec{\phi}^{\intercal} \vec{P}_j^{-t} \tag{B5}$$

For each of the three estimated values for PCP adherence, the higher the adherence is, the higher the PCP quality. Although there is variation in PCP adherence each year, overall, each measure is fairly stable across years. Consequently, using the average of adherence across years and using the estimated adherence for each year generate similar results. To better understand the validity of my estimated adherence ("value-added"), I check the relationship between these measures and PCP age, board certificate, medical school ranking, and medical degree in Table A3. As shown in the table, board certification, medical school ranking, and having a Doctor of Medicine (MD/DO) degree are all positively correlated with a PCP's adherence to recommended preventive procedures. In addition, as expected, PCP adherence has an inverted U-shape with PCP age. The positive correlation between my estimated PCP adherence and other high-quality indicators demonstrates the validity of using PCP adherence to preventive procedures as a measure of PCP quality.

However, Kane and Staiger (2008) and Chetty et al. (2014) both show that once students' lagged test score is controlled for, student sorting becomes negligible in estimating teacher value-added. I control for lagged preventive procedure use following the teacher value-added literature. However, due to a continuous patient–physician relationship, lagged preventive procedure use might not be good at eliminating patient sorting. The extent to which lagged preventive procedure use can help to address patient sorting is an empirical question, which is left for future research. Results with physician value-added used in this paper are only suggestive evidence.

Appendix C General Treatment and Control Groups, Normal and Early Retirements

Sections 4 and 5 present my main estimates of the effects of normal PCP retirement on patient outcomes. This section provides results from the general treatment and control groups (columns [1] and [3] in Table 1) regarding the general PCP retirement effects. The sample used for the analysis includes all patients whose initial PCP retired between 2010 and 2013 at any age and a random 10% sample of all patients whose initial PCP had not retired by 2013. As we can tell from Figures C1 to C11, the estimated effects from this general sample have the same directions as the main estimates. However, the magnitude and the dynamic patterns are different for several outcomes.

Figure C1 indicates a similar decline in primary care utilization at the extensive margin, but unlike the temporary increase in conditional costs shown in Figure 2, there is a persistent decline at the intensive margin. As time passes, the decline is even larger, which results in a decreasing average primary care cost. Figure C2 demonstrates that this persistent decline in conditional primary care costs is driven by the early retirement of PCPs. The effects of normal PCP retirement are similar to the main estimates based on the matched sample. However, the downward pre-trends in conditional primary care costs among patients whose initial PCP retires at ages 50–54 and 55–59 suggest that early retirements are not exogenous, consistent with what we find in Figure A1. These early retirements seem to be driven by the declining performance of PCPs on patient care.

Cardiology care in Figure C3 and the use of medical tests in Figure C4 are similar to my main estimates. However, the utilization of ER and prescription drugs in Figure C3 and the utilization of inpatient care in Figure C5 show different dynamic patterns. In contrast to the short-term increases in emergency care and inpatient care utilization and unlike the minimal effect on prescription drug use from my main estimates, here I find persistent increases in all three forms of care. As a result, total quarterly per capita medical costs also increase persistently by over $100 as shown in Figure C6. When examining changes in total Medicare costs by PCPs' retirement age, Figure C7 shows that the persistent increase in medical costs is driven by early retirements.

Regarding the quality of care, Figure C8 shows that PCP retirement has no impact on patients' mortality rate. However, Figure C9 shows that hospitalization rates due to acute ACSCs and congestive heart failure increase after PCP retirement with a bigger magnitude than my main estimates. As for the detection of new chronic conditions, the overall effect is similar to my main estimate, as shown in the third graph in Figure C4. Then, Figure C10 further investigates the effects by PCP age at retirement. Although both early (except for PCPs who retire before age 45) and normal retirements lead to an increase in detection, the impact is greater among patients whose PCP retires after turning 60. Finally, Figure C11 illustrates similar increases in the replacement PCP's adherence to the three preventive procedures, but all with an upward pre-trend.

Overall, estimates based on the general treatment and control groups are greater than those from the matched sample with normal PCP retirements. The results by PCP retirement age demonstrates that the larger effects are mainly driven by the early retirements. Although due to the endogenous timing of early retirements, we cannot make any causal inference, the above evidence suggests that early retirements of PCPs are much more costly and lead to less improvement in care quality (and worse quality on avoidable hospitalizations) than normal retirements of PCPs.

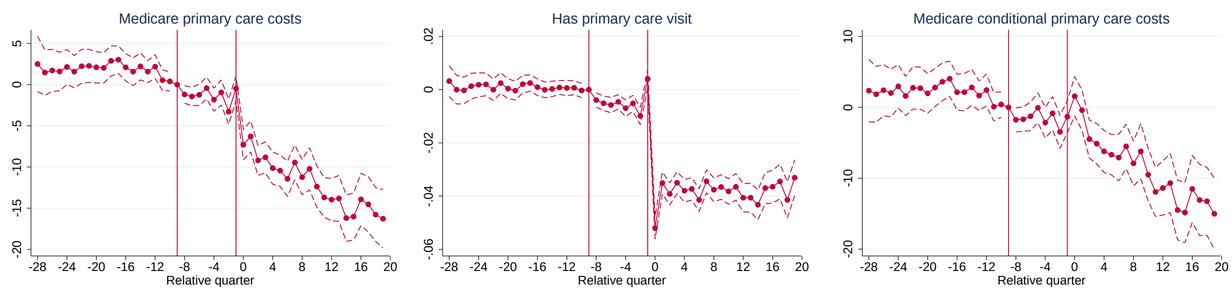


Figure C1: Effect on Primary Care Utilization: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Regression coefficients from event studies in equation (1) are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Relative quarters are calculated with respect to a patient's initial accountable PCP's retirement date. Quarter -9 is set as the reference quarter to account for potential anticipatory behavior between relative quarters -8 and -1. PCP visits and costs include not only visits to a patient's accountable PCP but also visits to any other PCP. Average primary care costs consist of per capita Medicare spending on primary care per quarter. Having a PCP visit (extensive margin) is a dummy variable, indicating whether a patient has at least one PCP visit in a relative quarter. Conditional costs (intensive margin) are calculated only if a patient has a PCP visit in a quarter. All costs are measured in 2010 USD.

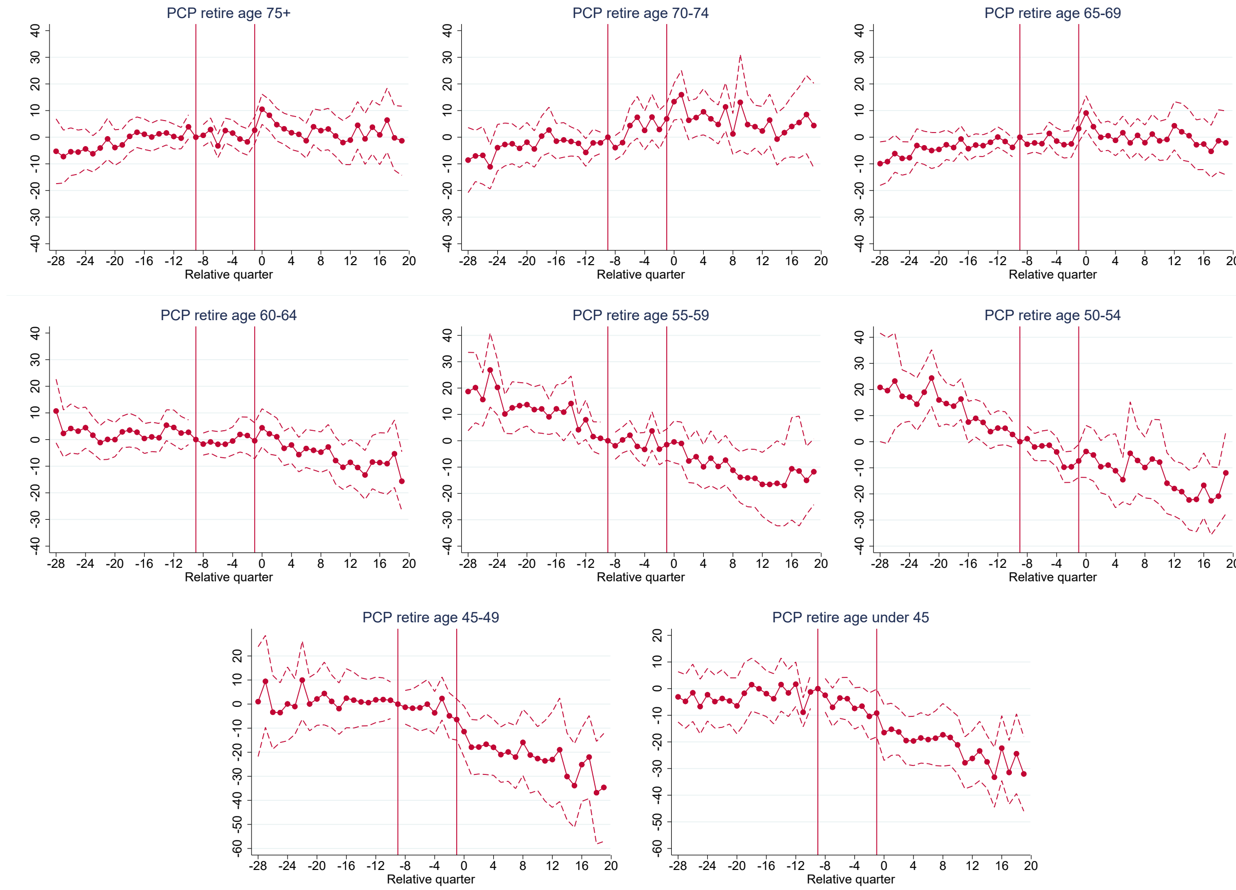


Figure C2: Changes in Conditional Primary Care Costs by PCP Retirement Age: General Sample

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

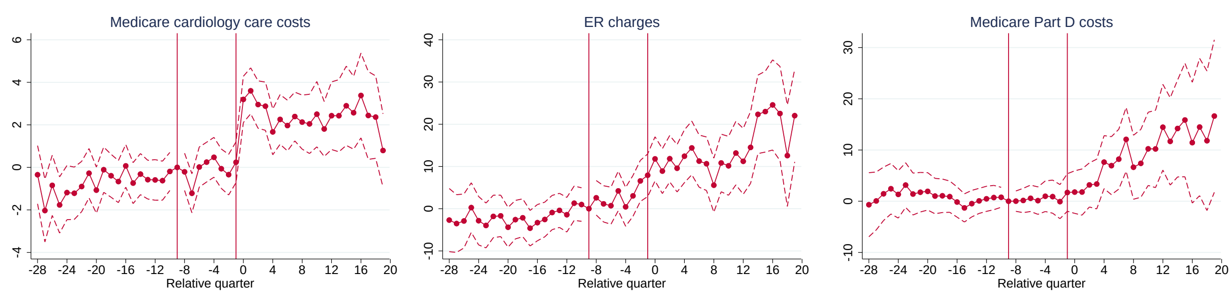


Figure C3: Effect on Other Forms of Health Care Use: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

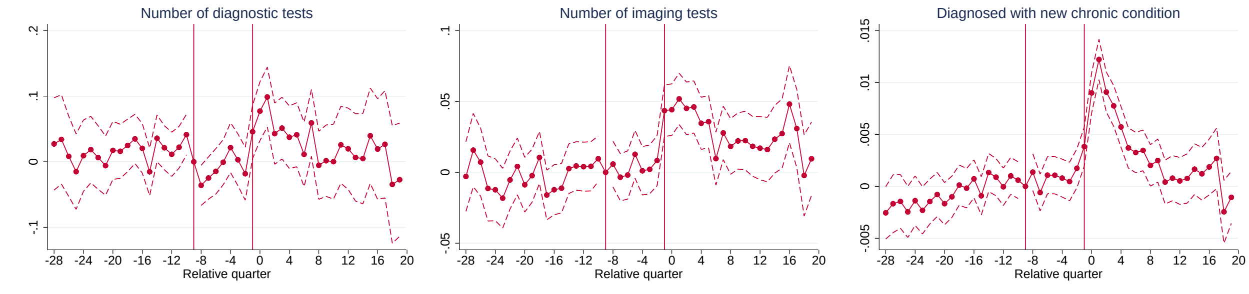


Figure C4: Effect on Medical Test Use and Diagnosis: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

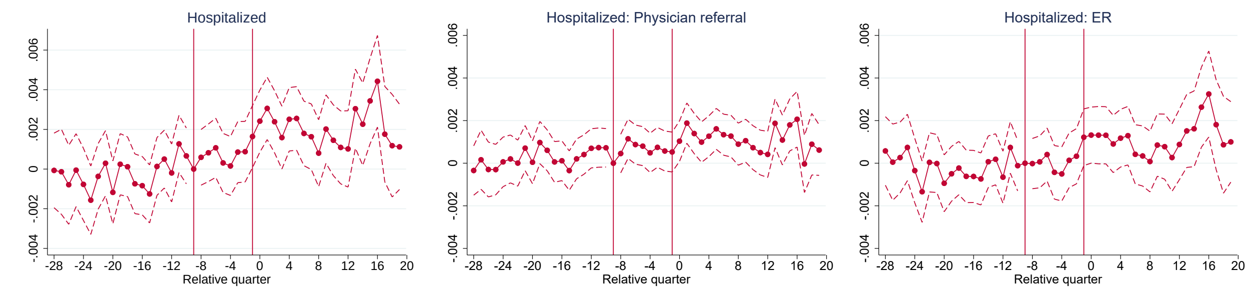


Figure C5: Effect on Hospitalization: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. It is possible for a patient to have inpatient admissions due to physician referral and through the ER in the same relative quarter.

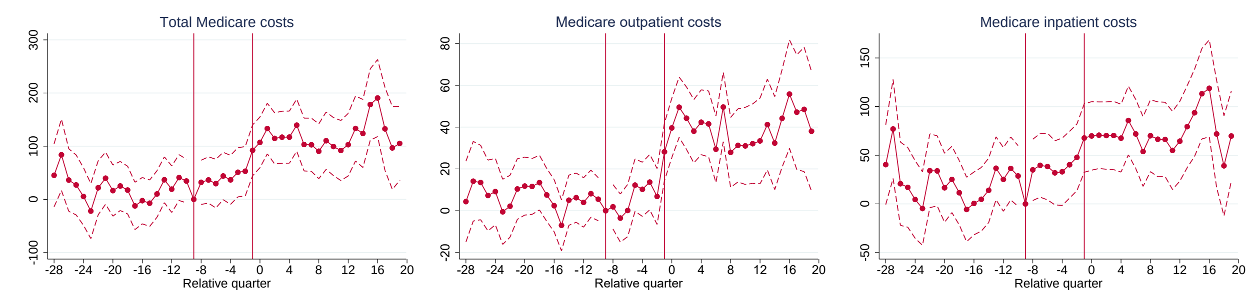


Figure C6: Effect on Medicare Costs: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Total medical costs include inpatient care costs, outpatient care costs, prescription drug costs, and skilled nursing facility costs.

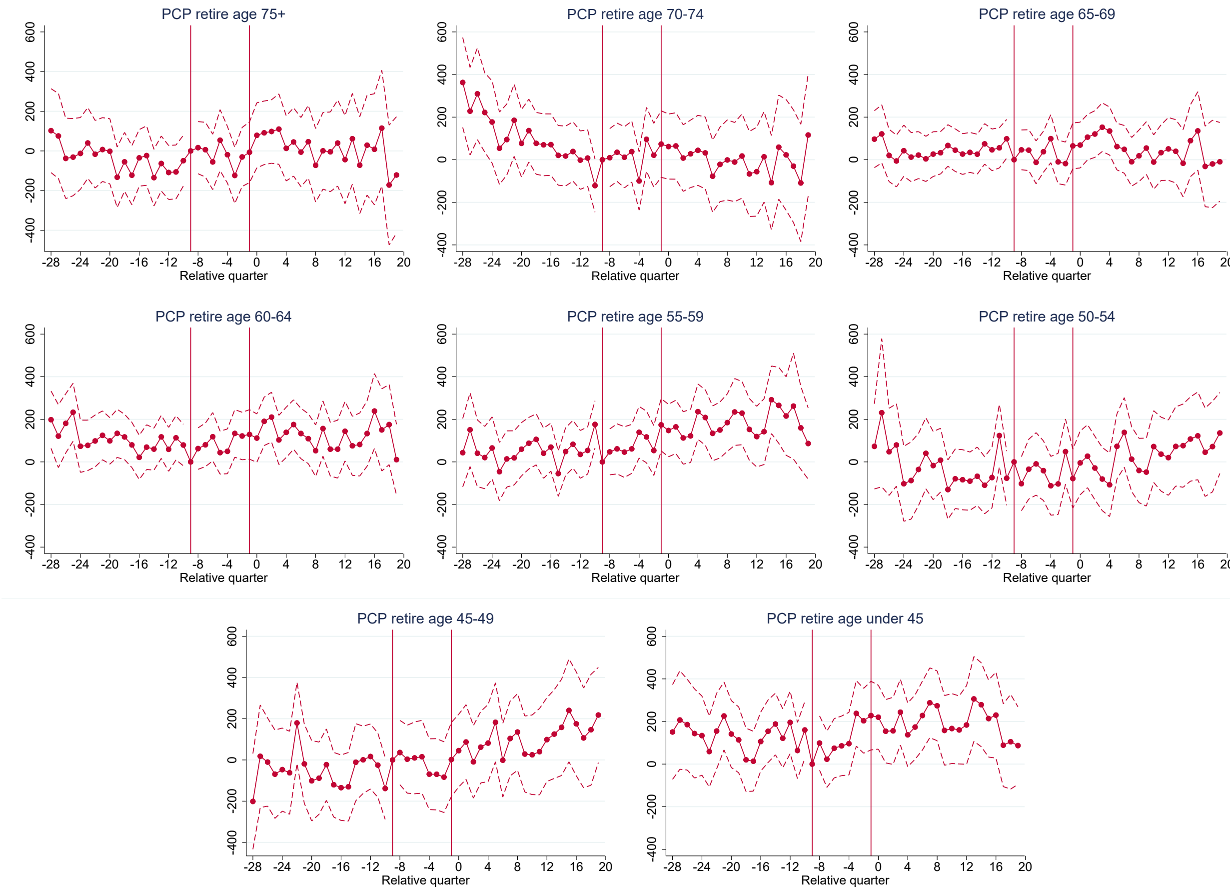


Figure C7: Effects on Total Medicare Costs by PCP Retirement Age: General Sample

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

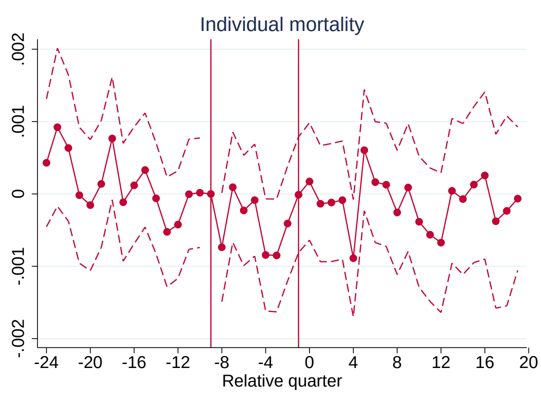


Figure C8: Effect on Individual Mortality: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from the event study are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

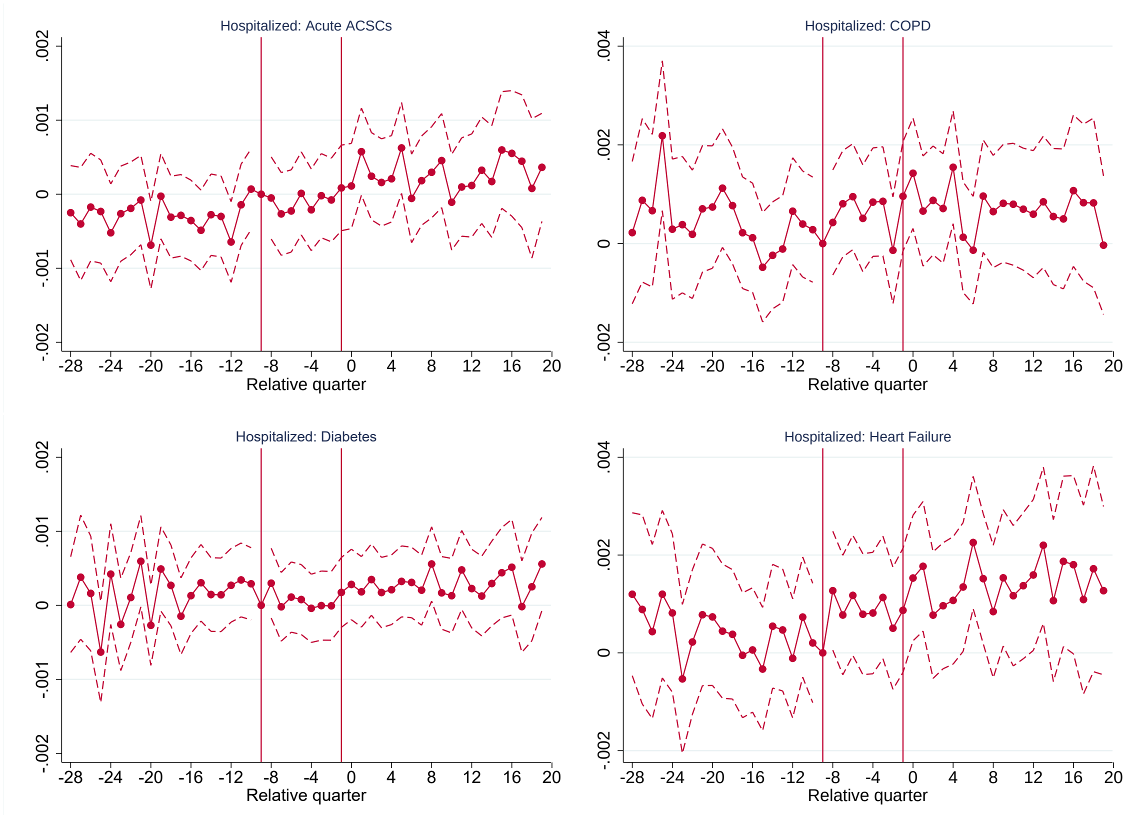


Figure C9: Effect on Potentially Avoidable Hospitalizations: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. Only observations before October 1, 2015 are included in the analyses due to the switch from ICD-9 to ICD-10 code in October 2015. For chronic ACSCs, only data from calendar year $t + 1$ are included in the analyses after patients were first diagnosed with a chronic condition in year t.

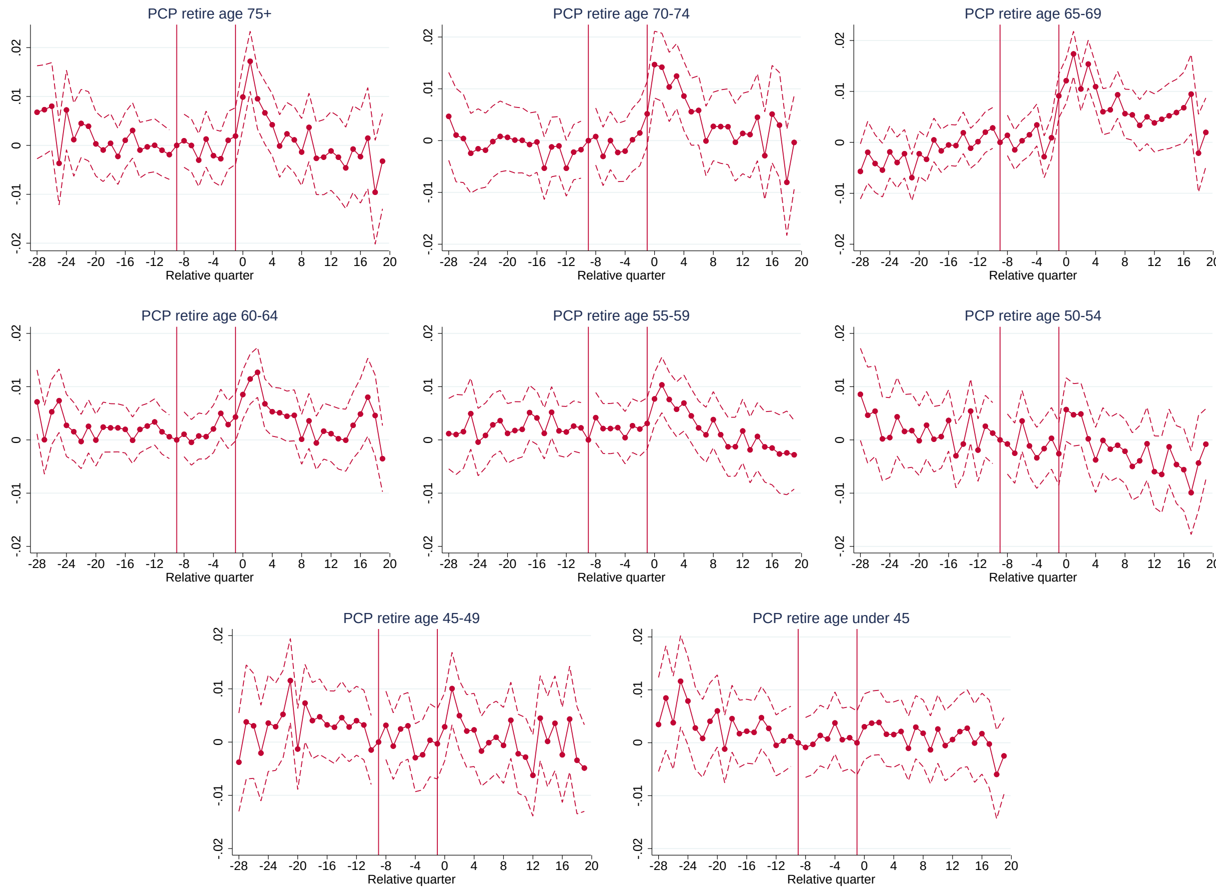


Figure C10: Effects on Chronic Disease Detection by PCP Retirement Age: General Sample

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level.

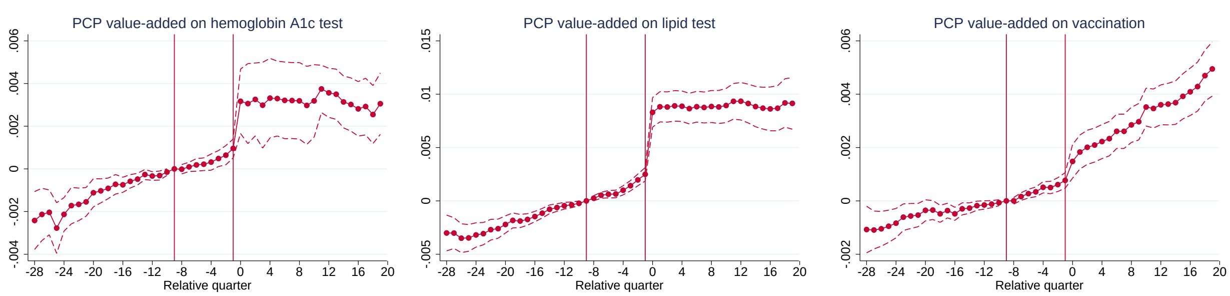


Figure C11: Changes in Accountable PCP's Quality: Any PCP Retirement

Notes: Patients with an initial PCP who retired between 2010 and 2013 at any age and 10% of patients whose initial PCP had not retired by 2013 are included in the analysis. Coefficients from event studies are plotted, and the dashed lines indicate the 95% confidence interval. Standard errors are clustered at the initial accountable PCP level. The outcome variables are accountable PCPs' adherence to the three recommended procedures. In each relative quarter, only patients who had at least one accountable PCP visit are kept for analysis.