SOCIAL ISOLATION AND DELAYED ALZHEIMER'S DISEASE AND RELATED DEMENTIAS DIAGNOSIS DURING THE COVID-19 ERA

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Abstract

Timely accurate diagnosis of Alzheimer's disease offers patients and their families the opportunity for early treatment with drugs that may slow disease progression, implementation of coordinated care plans, better management of symptoms, higher levels of patient safety, and cost savings. However, the COVID-19 pandemic has created additional challenges for the delivery of non-COVID-19 related healthcare, and may be associated with delays in initial ADRD diagnosis. Using data from a large comprehensive database of capturing medical and prescription drug claims for approximately 15 – 20 million annual lives from both commercial and MA enrollees dispersed across all 50 U.S. states, and quasi-experimental designs we examine pandemic induced changes in initial ADRD diagnosis by comparing cumulative rates of new ADRD diagnosis in two cohorts of ADRD naive patients, of ages 65+ years, between January 2018 and February 2021. The early results show that the cumulative rate of initial ADRD diagnosis rates significantly declined by about 9.5% at the onset of the pandemic, following the start of the social isolation period in March 2020. We also observe some recovery of initial ADRD diagnosis starting around the COVID-19 vaccination rollout in December 2020, which may mark the scaling back of social isolation. Considering heterogeneity of effects, we observe similar trends of shortfall in new ADRD diagnosis for all, but particularly for female, patients of ages 80+ years and Asian patients, during the initial social isolation period of COVID-19 pandemic in samples stratified by age, gender and race/ethncity. We also note that the recovery of new ADRD diagnosis following the COVID-19 vaccination rollout was stronger among female patients and patients of ages 80+ years, who had experienced the larger early pandemic declines in new diagnosis, but was concentrated only in White patients. Overall, our results suggest that the pandemic induced a shortfall of 958 initial diagnosis of ADRD compared to prepandemic years and may be associated with additional healthcare costs ranging from about $15-$129 million dollars, largerly driven by sub-optimal management of comorbidities, like diabetes, in patients yet undiagnosed with Alzheimer's disease and related dementias, resulting in hospitalizations that might have been avoided if earlier AD diagnosis and resulting care plans had been in place.

1 Introduction

Timely diagnosis of Alzheimer's disease, the leading cause of dementia (ADRD), potentially offers patients and their families the opportunity for early treatment with drugs that may slow disease progression, implementation of coordinated care plans, better management of symptoms, higher levels of patient safety, and cost savings (Dubois et al., 2015). Early therapeutic interventions can be effective in improving cognitive function, treating depression, improving caregiver mood, and postponing institutionalization. Some of these interventions may be more effective when started earlier in the disease course (Prince, Bryce, and Ferri, Prince et al.) and older adults with probable dementia who have not yet received a dementia diagnosis are more likely to report engaging in potentially unsafe behaviors including driving, preparing hot meals, managing finances or medications, attending doctor visits alone or reside in unsafe living conditions resulting in falls and other unmet needs (Amjad et al., 2016). Early diagnosis is not a panacea, of course. There is some evidence that early detection is not associated with reduced ED visits (Couch et al., 2021), and researchers are also cautious of the possibile harms of over-diagnosis that could happen if patients are diagnosed and treated without symptoms (Langa and Burke, 2019).

Healthcare providers sometimes delay ADRD diagnosis because of stigma, suicide risk, lack of training, diagnostic uncertainty, shortage of specialized diagnostic services, and the lack of effective disease-modifying options (Dubois et al., 2015). However, the COVID-19 pandemic has created additional challenges for the delivery of non-COVID-19 related healthcare. The pandemic has forced the healthcare sector to pivot its attention to COVID-19 prevention, detection, and treatment, upending established norms of care and creating significant declines in provision of non-COVID-19 acute care and preventive/primary care during the pandemic (Ziedan et al., 2020).The pandemic may have delayed timely diagnosis of new health conditions. However, as yet, there is little evidence whether the pandemic induced disruptions in routine healthcare delivery were associated with delayed initial ADRD diagnosis, which may have subsequently delayed therapeutic interventions, life style changes and planning, and caused irreversible rapid disease progression.

The federal government declared the pandemic a state of emergency on 13 March 2020. Following the federal emergency declaration, many states implemented policies including stay-at-home orders to induce social distancing and curb the transmission of the virus. Most states also implemented targeted social distancing policies to specifically protect the elderly against the virus, including extended nursing home visitation bans, which almost completely socially isolated the elderly living in assisted care and long-term care facilities. While mandated and voluntary social isolation of the elderly may have helped lower the transmission of the virus, these measures may have also restricted elderly persons ability to access timely non-COVID care.

Pandemic-induced dramatic social isolation may have disparately impacted individuals at risk of ADRD. Age is the strongest risk factor associated with ADRD, and during COVID-19 older individuals or their caregivers may also have voluntarily forgone in-person non-COVID care due

to the potential risk of contracting the virus while visiting a healthcare facility, which has led to over 1 million deaths in the U.S. by May 2022, eighty percent of which were among persons aged 65 years and older (CDC, 2022). Additionally, non-urgent healthcare delivery was suspended or limited to telehealth modalities to ease the burden on healthcare systems overwhelmed by COVID care needs. However, quarantined, elderly individuals, with possible mild cognitive impairment, which frequently precedes Alzheimer's disease diagnosis, may be less able to access health and social care via telehealth modalities, without help. Moreover, frequently used services like brain imaging, laboratory testing, and physical and mental therapies to diagnose Alzheimer's disease cannot be easily provided via telehealth, and may lead to delayed diagnoses and subsequent sub-optimal clinical management of the disease and its symptoms. Socially isolated patients with mild cognitive impairment (MCI) or probable ADRD, living independently, may find their medication management, prescribed medication modification and/or new medication initiation more challenging.

For the first 10 months of the pandemic, non-pharmaceutical interventions like social distancing and mask wearing were the only means to keep viral transmission in check. The first COVID-19 vaccine (Pfizer-BioNTech) was approved for emergency use by the U.S. Food and Drug Administration (FDA) on December 11, 2020. Vaccines manufactured by Moderna and Johnson Johnson were approved on December 18, 2020 and February 27, 2021 respectively. These vaccines have significantly helped flatten the COVID-19 trajectory in the U.S. (Gupta et al., 2021). After an extended period of social disruption, the state COVID-19 vaccination campaigns have allowed the U.S. healthcare sector to turn its attention back to important non-COVID-19 related care and for many older Americans to socially engage and access non-COVID-19 care again safely for the first time since the start of the pandemic. Scaling back of social-isolation following COVID-19 vaccination rollouts may may lead to some 'recovery' in initial ADRD diagnosis. Additionally, physical activity and mental and social engagement are proven to be protective against rapid decline in cognitively impaired individuals (Gupta, 2018) and social isolation during the pandemic may have led to faster cognitive decline to detectable levels in patients at risk of ADRD, and incidence of new ADRD may in fact be even higher during the pandemic than in typical years. Therefore, any observed shortfalls in initial ADRD diagnosis during the pandemic compared to other years likely capture a lower bound of reductions in initial ADRD diagnosis. However, to our knowledge, no study yet has examined whether state vaccination campaigns were associated with recovery in initial diagnosis of ADRD.

Using quasi-experimental designs, this study contributes to the literature in two ways. First, we examine the impact of the COVID-19 pandemic on the incidence of initial Alzheimer's disease and related dementia (ADRD) diagnosis among ADRD naive patients in the U.S. Delays in initial ADRD diagnosis during the pandemic will be additional evidence of the broader public health impact of the pandemic due to additional when additional non-COVID-19 morbidity and mortality. Second, we examine whether renewed social engagement and opportunities for healthcare access, since the start of the state vaccination campaigns, captured using the timing and rate of state/ county

vaccination rates, is associated with recovery of initial Alzheimer's disease and related dementia (ADRD) diagnosis among ADRD naive patients in the U.S. Evidence of catch-up in delayed initial ADRD diagnosis following the COVID-19 vaccination roll out would support the broader public health role of the COVID-19 vaccines in increasing utilization of recommended non-COVID-19 related care.

2 Background

The five stages of Alzheimer's disease are preclinical Alzheimer's disease when most patients experience no noticeable symptoms, mild cognitive impairment (MCI) due to Alzheimer's disease where individuals may experience mild memory lapses but may still not be significant enough to affect work or relationships yet, mild dementia due to Alzheimer's disease, moderate dementia due to Alzheimer's disease and severe dementia due to Alzheimer's disease, where in the last 3 stages with some dementia patients experience a group of symptoms that affect intellectual and social abilities severely enough to interfere with daily function (??, May). The rate of progression for Alzheimer's disease varies widely, with people with Alzheimer's disease, on average, surviving between 3-11 years after diagnosis, but some may live as long as 20 years post-diagnosis.

2.1 Disease management, planning and quality of life

Despite limited availability of well established disease-modifying agents capable of reversing pathological changes associated with Alzheimer's disease, a large body of literature has established the value of an early and accurate diagnosis for several reasons (Chandra et al., 2020). First, it may be possible to prevent or delay the development of dementia in a proportion of the population through lifestyle changes or modifying exposure to common risk factors (Rasmussen and Langerman, 2019; Dubois et al., 2015; Prince, Bryce, and Ferri, Prince et al.). For instance, certain healthier diets and regular physical exercise have been found to be strongly associated with delayed dementia progression (Ahlskog et al., 2011; George and Reddy, 2019; Brasure et al., 2018). Other noted modifiable-risk factors associated with slower AD progression include increasing cognitive stimulation and social engagement, and improved management of co-morbid conditions like diabetes and depression (Dafsari and Jessen, 2020; Bartels et al., 2018; Cantón-Habas et al., 2020).

An accurate Alzheimer's disease diagnosis earlier in the disease trajectory may also allow patients to access approved pharmacotherapies available to better manage the disease, which may improve their quality of life and reduce caregiver burden. Currently only one medication, Aducanumab (Aduhelm™), has received FDA approval for use in patients with MCI and early AD on the basis of early evidence of being able to 'treating the disease' by targeting beta-amyloid, a microscopic protein fragment that forms in the brain and accumulates into plaques leading to

neurodegeneration associated with AD. Although more trials are underway to examine additional evidence to support this claim, there are other drug classes like Cholinesterase inhibitors (Aricept®, Exelon®, Razadyne®), Glutamate regulators (Namenda®) and combination formulations of the two (Namzeric®) with well established clinical evidence of success in limiting or stabilizing cognitive symptoms for a limited time, particularly in the early stages of the disease (Cui et al., 2019). Improved cognition (memory and thinking), even if only temporarily, is associated with improved instrumental activities of daily living (IADLs) and activities of daily living (ADLs), which may reduce caregiver burden and delay institutionalization.

Timely diagnosis of AD may also be important to plan better for what lies ahead. There is evidence that complex tasks like managing finances begin becoming difficult relatively relatively early in the trajectory of cognitive decline associated with AD (Nicholas et al., 2021) and the rate of functional decline accelerates along the AD continuum (Dubbelman et al., 2020; Fieo et al., 2018). Timely diagnosis will allow patients to start planning early and reduce subsequent caregiver burden.

Finally, having an AD diagnosis is essential to enroll in the many clinical trials that are currently underway and enrollment at an early stage of the disease is preferable at the individual level as well as for the scientific longitudinal study process.

Despite the many advantages of a timely AD diagnosis, accurate diagnosis is critical. Misdiagnosis may elevate patients risk of depression and suicide, and result in treatment with medications with known adverse effects for normal aging related MCI. Accurate diagnosis of the disease requires advanced imaging that can identify deposits of a protein called amyloid-beta that is a trademark of Alzheimer's disease, which is costly. Additional supportive evidence from bio- and genetic- markers collected by means of blood work and genetic testing may further improve the accuracy of the diagnosis, particularly at early stages. However, both in person imaging and testing may have been limited during the early months of the COVID-19 pandemic due to the need for social distancing, thereby delaying diagnosis.

2.2 Cost implications

Quantification of cost-implications for delayed AD diagnosis is challenging due to the variation in the speed of progression of the disease, complex care needs of patients, and the large share of informal care-giving cost that continues to be hard to impute (in 2017, caregivers of people with Alzheimer's or other dementias provided an estimated 18.4 billion hours of unpaid assistance, a contribution to the nation valued at $232.1 billion.). A 2022 annual report of the Alzheimer's Association shows that diagnosis in the MCI stage rather than the dementia stage or not at all would imply an estimate of about $7 trillion saving in direct health care costs, with potential savings attributable to a smaller spike in costs immediately before and after diagnosis and lower medical and long-term care costs for individuals who have diagnosed and managed MCI and dementia compared with individuals with unmanaged diseases (??, noa). Getsios et al. (2012) provide a simulation based economic evaluation

of early assessment for Alzheimer's disease in the United Kingdom and show that compared with no early assessment, identifying patients in early-stage AD (which was assumed to include a visit to a general practitioner, two specialist visits, laboratory tests, and a magnetic resonance imaging or computed tomography scan) could produce downstream cost savings ($3100 per patient, with an additional $5300 in savings attributable to reductions in caregiver time costs) and health benefits, despite significant up-front costs. These findings are corroborate an earlier US study (Weimer and Sager, 2009). In all of these studies the economic value of detecting AD/ADRD in its early stages are based on targeting resources to individuals most likely to benefit from intensive workup and follow-up care, for instance those with existing genetic- or bio- markers for the disease.

In addition to value of early diagnosis, there are also simulation based economic evaluations of early treatment for ADRD, based on hypothetical disease-modifying therapies. For instance, Green et al. (2019) show that disease-modifying therapy for MCI due to AD may be associated with $11,330 incremental costs (2017 dollars) and 0.224 incremental quality-adjusted life years, compared to usual care. In this case, the hypothetical MCI treatment had an incremental cost-effectiveness ratio of $50,542 per quality-adjusted life year, suggesting reasonable value for money based on commonly cited cost-effectiveness benchmarks (i.e., below $100K-150K per quality-adjusted life year). While this study seems very rigorous it does assume that the hypothetical MCI intervention costs $5,000 per (much lower than that the $56k cost for the first FDA approved, potentially disease modifying medication, Aduhelm™) and would reduce the risk of conversion from MCI to AD by 20% (comparable to Aduhelm's phase 3 estimates of 22% reduction decline from high-dose use over 76 weeks).

Just considering savings in healthcare costs, existing literature suggests that routine screening that identified patients with early signs of dementia helped cut average healthcare costs, with estimates ranging from about $1,700 per patient in the first year (by eliminating money spent on unnecessary tests and treatments, (McCarten et al., 2010)) to nearly $14,000 per patient, on average, per year they remain undiagnosed (Alz, 2018), driven largely by comorbidities, as patients with undiagnosed AD would be at greater risk for mismanaging their other comorbid conditions like diabetes, resulting in hospitalizations that might have been avoided were prior care plans for AD had been in place. Overall, findings in the health economics literature suggest that delaying the disease progression to full-blown AD/ADRD may result in economic benefits, but it remains unclear whether any savings generated from early detection and early treatment will be large enough to offset downstream long-term costs.

3 Data

3.1 Data Sources

To examine the extent of pandemic induced changes in initial diagnosis of ADRD we used a comprehensive claims database, which includes approximately 15 – 20 million annual lives from both commercial and MA enrollees dispersed across all 50 U.S. states. The database provides demographics, medical claims for both outpatient and inpatient services with regular follow-up until either their death or membership discontinuation.

To examine the extent to which pandemic changes in initial ADRD diagnosis may be associated with social isolation of older patients during the pandemic we will examine measures of mobility to assisted living and long term care facilities, constructed using cell phone 'pings' from 29 million mobile phones from SafeGraph. The SafeGraph data have been extensively used to measure social distancing (Jay et al., 2020; Allcott et al., 2020; Chang et al., 2021), transmission of COVID-19 (Gao et al., 2020), and trends in visits to specific locations during the pandemic (Goolsbee and Syverson, 2021; Jay et al., 2020; Cantor et al., 2022). We will examine mobility trends using Point of Interest (POI) data for each state starting from 2018 and until the current time and will identify assisted living and long-term care facilities using 2-digit U.S. Census NAICS codes). These cell-phone based "foot traffic" data serve as proxy measures for the extent of social contact of elderly patients residing in assisted/long-term care facilities with the 'outside world' throughout the pandemic.

3.2 Sample construction

3.2.1 Treatment and control cohorts

Using the claims database we construct 2 cohorts of ADRD naive patients - a pre-pandemic control cohort and a pandemic treatment cohort. Figure 2 describes the cohort construction. The pre-pandemic control cohort includes individuals ages 65+ years in 2018, who were continuously enrolled with the insurer and who remained living and never had an ADRD diagnosis (definition described below) throughout the 'baseline period of' January 2018 through June 2018. The pre-pandemic control cohort was then further restricted to include individuals who continued to remain continuously enrolled with the insurer or until their month of death during the 'follow-up period' of July 2018-February 2020. The pandemic treatment cohort was similarly constructed to include individuals ages 65+ years in 2019, who were continuously enrolled with the insurer and surived without an ADRD diagnosis throughout the 'baseline period of' January 2019 through June 2019, and remained continuously enrolled with the insurer or until their month of death during the 'follow-up period' of July 2019-February 2021.

3.2.2 ADRD Definition

We used two methods to identify ADRD diagnoses. First, we used diagnosis codes from inpatient and outpatient medical claims to identify diagnostic ADRD among the study population (ages 65+years, continuously enrolled, and not deceased during baseline period). Patients with at least one inpatient claim or two outpatient claims at least 7 days apart with a qualifying diagnosis during the baseline period for each cohort (January 2018 through June 2018 for the prepandemic and January 2019 through June 2019 for the pandemic cohorts) were identified as having baseline ADRD and were excluded from the sample. For the individuals identified as ADRD-naive, we then traced out instances of first observed ADRD diagnosis during their 20-month (or until death during) follow-up period. Second, we used the American Hospital Formulary Service (AHFS) classification system to identify ADRD specific prescription drug claims for the individuals in the study population (ages 65+years, continuously enrolled, and not deceased during baseline period), excluding those with ADRD specific prescription drug claims during the baseline period and tracking the first instance of ADRD specific prescription drug claim during the follow-up period. The two alternative measures of ADRD - diagnosis based and prescription drug utilization based - were a nearly perfect match, which is not surprising given that the medications considered are highly specialized for management of ADRD.

3.3 Cumulative rate of initial ADRD diagnoses

For the ADRD naive patients, of ages 65+years, who remain continuously enrolled, and not deceased during the baseline period, in both the pandemic and pre-pandemic cohort, we track receipt of initial ADRD diagnosis during the follow-up period (20-months between July 2019/2019-February 2020/2021 or until death) and create a measure of cumulative new ADRD diagnosis over time in the pandemic cohort and separately for the control cohort. The final outcome is constructed as the aggregate cohort-state-month rate of cumulative initial ADRD diagnosis rate over time, and is calculated as the share of the ADRD naive patients in the cohort-state who have received an initial ADRD diagnosis by a given month.

3.4 Non-parametric analysis

Figure 1 shows measures of mobility to senior living facilities during January 2020 through February 2021, from the Places of Interest (POI) data from SafeGraph Aggregated Mobility Metrics. Smartphone mobility data are provided at the individual POI level, and nursing home locations are identified using 6-digit North American Industry Classification System (NAICS) code (the taxonomy developed by the US Census Bureau). Each grey line represents a U.S. state, which turn red after the state implements stay-at-home orders, orange following official state re-opening, and green following state COVID-19 vaccination roll out. Progressively darker shades of green capture

percentage of the state - 10%, 20%, 40% and 60% - vaccinated. The thick black line represents a "smoothed" 7 day moving average of the states capturing national trend. We find that the onset of the pandemic were associated with sharp decline in mobility to senior living facilities, suggesting that the onset of the pandemic may have started the "social isolation period", and the COVID-19 vaccination rollout in the middle of December 2020 began to scale back social isolation during early 2021.

Table 1 descriptively compares the pandemic and control cohort constructed using our claims database . From columns 1 and 3, we note that the pandemic and control cohorts are very similar in their demographic characteristics. We also note that 1.6% (42,581/2,675,835) of the control cohort receives an initial ADRD diagnosis during the follow-up study period, and is somewhat bigger than the previously reported rate (from 2007) of approximately 500,000 new ADRD diagnosis nationwide each year (Hirtz et al., 2007). Similar to prior literature, the subset of the patient's who receive an ADRD diagnosis tend to be, on average, 4 years older, female and suffer from more comorbidities.

Figure 3 correlates the national trend in proxy social isolation measure during July 2019-February 2021 with trends in cumulative initial ADRD diagnosis rates in the pandemic and the control cohorts. From Figure 3 we note that the cumulative rate of initial ADRD diagnosis rates nearly coincided for the pandemic and the control cohorts prior to the pandemic onset, but starts to diverge, with reductions in initial ADRD diagnosis during the pandemic, following the start of the social isolation period. We also observe slight recovery of initial ADRD diagnosis starting around the COVID-19 vaccination rollout that may mark the scaling back of social isolation. Figures 4-6, mimic similar trends of shortfall in new ADRD diagnosis for all, but particularly for female, patients of ages 80+ years and Asian patients, during the initial social isolation period of COVID-19 pandemic in samples stratified by age, gender and race/ethncity. We also note that the recovery of new ADRD diagnosis following the COVID-19 vaccination rollout was stronger among female patients and patients of ages 80+ years, and was concentrated in White patients but not observed among racial/ethnic minority patients.

4 Methods

We use event study regression models to examine how cumulative rates of new ADRD diagnosis evolved during the period leading up to and following the onset of the COVID-19 pandemic in March 2020 by comparing accumulation of new ADRD diagnosis in the 20-month follow-up period of the pandemic cohort (July 2018-February 2020) with those in the 20-month follow-up period of the control cohort (July 2019-February 2021). Our event study estimates shed light on whether the pandemic has been associated with delayed initial diagnosis of ADRD. Let $PostMarch_c$ be the indicator for March (i.e. March 2019 for control and March 2020 for treatment) for each cohort $c \in \{control, treated\}$. Then $TSE_{cst} = t - PostMarch_c$ measures the number of months

between month-year $t \in [-8, 11]$ and March for each cohort. For example, five months before March, $TSE_t = -5$. Five days after March, $TSE_t = 5$. We set $TSE_{cst} = 0$ for the control cohort that never experienced the pandemic, and we fit event study regression models with the following structure:

$$y_{cst} = \sum_{a=-8}^{2} \alpha_a 1\left(TSE_{cst} = -a\right) + \sum_{b=0}^{11} \beta_b 1\left(TSE_{cst} = b\right) + \mu_c + \theta_s + \gamma_t + \epsilon_{cst}$$

In the model, y_{cst} is the cumulative rate of new ADRD diagnosis in cohort $c \in \{control, treated\}$, in state s, in month-year $t \in [-8, 11]$. μ_c is the cohort c fixed effects to capture any fixed differences in the level of new ADRD diagnosis rates between the two groups, θ_s is a set of state fixed effects, which are meant to capture fixed differences in the level of outcomes across states that are stable over the study period. γ_t is a set of month-year fixed effects, which capture trends in the outcome that are common across all states and cohorts. ϵ_{cst} is a residual error term. α_a and β_b are event study coefficients that trace out deviations from the common trends that states in the treatment cohort experience in the months leading up to and following the onset of the pandemic in March 2020. Specifically, α_a traces out differential pre-March 2020 trends in the cumulative new ADRD diagnosis rates that are associated with treatment cohort. β_b traces out differential post-event trends in the in the cumulative new ADRD diagnosis rates that occur in the treatment cohort post pandemic onset in March 2020. The reference period in all event studies is the period before adoption, when $TSE_{cst} = -1$. We estimate standard errors using a cluster robust variance matrix that allows for heteroskedasticity and for clustering at the state level.

5 Results

5.1 Main results

In Figure 7, we present event study coefficients with 95% confidence bands from models examining the impact of the COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses (ADRD), for the full population of ADRD naive patients. In Table 2 we present the detailed event study regression results.

In line with the non-parametric evidence, the event study results suggest that the cumulative new ADRD diagnoses rate did not trend differentially from those of the prepandemic control group in the period leading up to the onset of the pandemic. However, we find statistically significant declines in cumulative new ADRD diagnoses rate in the first three months of the pandemic, suggesting that the onset of the pandemic induced immediate and substantial shortfalls in diagnoses of ADRD during the period of extreme social isolation. The event study coefficients imply that pandemic reduced the cumulative diagnosis rate by about 9.6% during the first 3 months, relative to the same period for the prepandemic control group, which serves as the baseline reference period for

effect size calculation (in percents) reported here. We also note from the event study results that the initial period of decline was followed by a slow recovery in cumulative initial ADRD diagnosis rates starting in June 2020 (only a 2.3% decline after 6 months of pandemic onset relative to the prepandemic cohort), but remained below prepandemic levels (though not statistically significantly lower at conventional levels) through until December 2020. Finally, we observe a rapid increase in cumulative new ADRD diagnosis rates once social isolation began scaling back post COVID-19 vaccination rollout, in fact rising above the prepandemic rates in the same period (an 8.9% increase relative to comparable months for the prepandemic cohort). Again, these later event-time estimates of recovery in initial ADRD diagnosis are much more noisily estimated and are not statistically significantly different from prepandemic levels for the comparable period at conventional levels.

5.2 Heterogeneity analyses

Figures 8-10 present event study estimates with 95% confidence bands of the impact of the COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses (ADRD), for samples of ADRD naive patients stratified by patient age (65-79 years and 80+ years), gender (female and male) and race/ethncity (Asian, Black, Hispanic and White). Higher age (Rajan et al., 2021) and female gender (Chêne et al., 2015) are highly predictive of ADRD, and these groups may thus experience larger pandemic induced shortfalls in initial diagnosis. We also consider heterogeneous impacts of the COVID-19 pandemic on initial ADRD diagnosis by patients' race/ethnicity, as there is evidence that racial/ethnic minorities have suffered disproportionately higher burdens of COVID-19 Gross et al. (2020) and non-COVID-19 morbidity and mortality (Friedman et al., 2021) and may have experienced greater losses in access to recommended non-COVID-19 related healthcare (Nguyen et al., 2022).

From Figure 8 we note that the cumulative new ADRD diagnoses rate did not trend differentially from those of the prepandemic control group for both age groups in the period leading up to the onset of the pandemic. Moreover, in line with the higher incidence of ADRD in older ages, the immediate shortfalls in intial ADRD diagnosis during the first 3 months of the pandemic are larger for patients of ages 80+years (-10.4%) than patients of ages 65-79 years (-8.2%) and are statistically significant at 95% level. However, the pandemic induced declines in initial ADRD diagnosis are more persistent in the younger cohort (ages 65-79 years), remaining significantly below prepandemic rates for comparable months until October 2020. In contrast, and similar to the 'full' sample, cumulative rate of initial ADRD diagnosis begins to recover for patients of ages 80+ years starting in June 2020, and then much more rapidly following the COVID-19 vaccine rollout; though, again, the individual event-time estimates during the 'recovery' period are not statistically significant for either age groups.

Event study results in Figure 9 show that the cumulative new ADRD diagnoses rates in the pandemic treatment cohort closely matched those for the prepandemic control group, for both

female and male patients, in the period leading up to the onset of the pandemic. Moreover, the incidence rates, as well as the pandemic induced significant shortfalls in initial ADRD diagnosis were comparable for both genders (-9.8% decline for women relative to -9.4% decline for men) during first 3 months of the pandemic. However, the shortfall in initial ADRD diagnosis was much more persistent for women (statistically significant 4.7% decline after 6 months of pandemic offset relative to comparable months for the prepandemic control cohort) than for male patients (no statististicaly significant difference relative to prepandemic group in initial diagnosis rates post 6 months post pandemic offset).

Finally, considering heterogeneous pandemic changes in cumulative initial ADRD diagnoses rates by patients' race/ethnicity, event study estimates presented in Figure 10 show that the cumulative new ADRD diagnoses rates in the pandemic treatment cohort closely matched those for the prepandemic control group, for each of the four race/ethnicity groups, in the period leading up to the onset of the pandemic. Moreover, pandemic induced significant shortfalls in initial ADRD diagnosis relative to prepandemic rates were experienced by all race/ethncity patient groups during the first 3 months of the pandemic, but were larger for Black and Hispanic patients than Asian and White patients (12% and 13.5% decline for Black and Hispanic patients, respectively, relative to 9.1% declines for Asian and White patients). Furthermore, after the immediate decline, intial ADRD diagnosis rates began to recover for White and Black patients starting June 2020, but remained significantly below prepandemic level for Asian and Hispanic patients for several more months following pandemic onset.

5.3 Back-of-the-envelope calculations of healthcare cost implications of pandemic delays in initial ADRD diagnosis

From Table 1 we note that by the end of the study period the cumulative initial rate of ADRD diagnosis in the control group was 1.6%. A comparable rate during the pandemic, would imply 43,344 new initial diagnoses of ADRD in the pandemic cohort compared with the realized 42,386, a deficit of 958 new ADRD diagnoses. While the 11-months post pandemic onset deficit in new ADRD diagnoses is small, its of concern as the rates continued to remain below those in the comparable control cohort, despite some recovery post-December 2020, and do not account for the irrecoverable welfare loss associated with delayed initial diagnosis during the early months of the pandemic. It is also worth keeping in mind that the study population is a large, but single insurer population. To give a rough sense of the magnitude of the pandemic shortfall in initial ADRD diagnosis in an all-payer population, there were 52,787,000 persons of ages 65+ years in the U.S. in 2019,[1] and a similar rate of missed/delayed intial ADRD diagnoses would imply a shortfall of 18,571 cases nationwide. Using existing estimates of missed healthcare cost savings associated with earlier and

[1]https://www.census.gov/data/tables/2019/demo/age-and-sex/2019-age-sex-composition.html

accurate ADRD diagnosis per patient in the first year, our results suggests that a half-year delay in initial ADRD diagnosis for 18,571 patients may imply, on average, additional healthcare costs ranging from about $15-$129 million dollars.[2] These cost estimates, however, do not take into account the potentially larger and persistent welfare losses associated with the delayed diagnosis for the patients and their caregivers. As more data become available it will be important to examine trajectories of healthcare utilizaton, health outcomes and patient and caregiver well-being for the cohort of ADRD patients whose initial diagnosis may have been delayed due to the pandemic.

6 Conclusion

The COVID-19 pandemic has disproportionately impacted the older patient population, who experienced higher rates of COVID-19 morbidity and mortality in the early days of the pandemic than any other subpopulation, and were thus subject to stricter voluntary and mandated social distancing to curb the transmission of the virus. Pandemic-induced dramatic social isolation and disruptions in delivery of non-COVID-19 health care may have disparately impacted individual's with mild cognitive impairment or probably dementia. Using claims data from a larger insurer capturing both commercial and MA enrollees dispersed across all 50 U.S. states, and quasi-experimental designs, our study finds that compared to a prepandemic period, during the initial months of the pandemic the cumulative rate of initial ADRD diagnosis rates significantly declined among ADRD naive patients of ages 65 years or older. We also find some evidence of recovery of initial diagnosis rates in the period following the rollout of the COVID-19 vaccination. However, overall, by the end of the study period, i.e. 11-months post pandemic onset, there remained a shortfall of 958 initial diagnosis compared to the prepandemic period. Considering the magnitude of the pandemic deficit in initial ADRD diagnosis across all payers, our estimates suggest that the pandemic may have induced nearly 18,000 fewer/delayed diagnosis, with large associated additional healthcare costs.

In subsequent analyses we plan to extend this early work in several ways. Estimates of savings associated with earlier and accurate ADRD diagnosis attribute savings to better management of comorbidities post-AD diagnoses, which may result in fewer inpatient episodes and better patient outcomes. Therefore, next we will compare pre- and post- ADRD diagnosis healthcare utilization of patients that received initial ADRD diagnosis in the pandemic and and control cohorts. Second, we hypothesize that probable dementia patients were more willing to seek care resulting in initial ADRD diagnosis once they received their COVID-19 vaccination. We will examine this further by studying the association between the timing of the patient's vaccination uptake, available in our claims database, and their initial ADRD diagnosis. Third, we will extend this work with

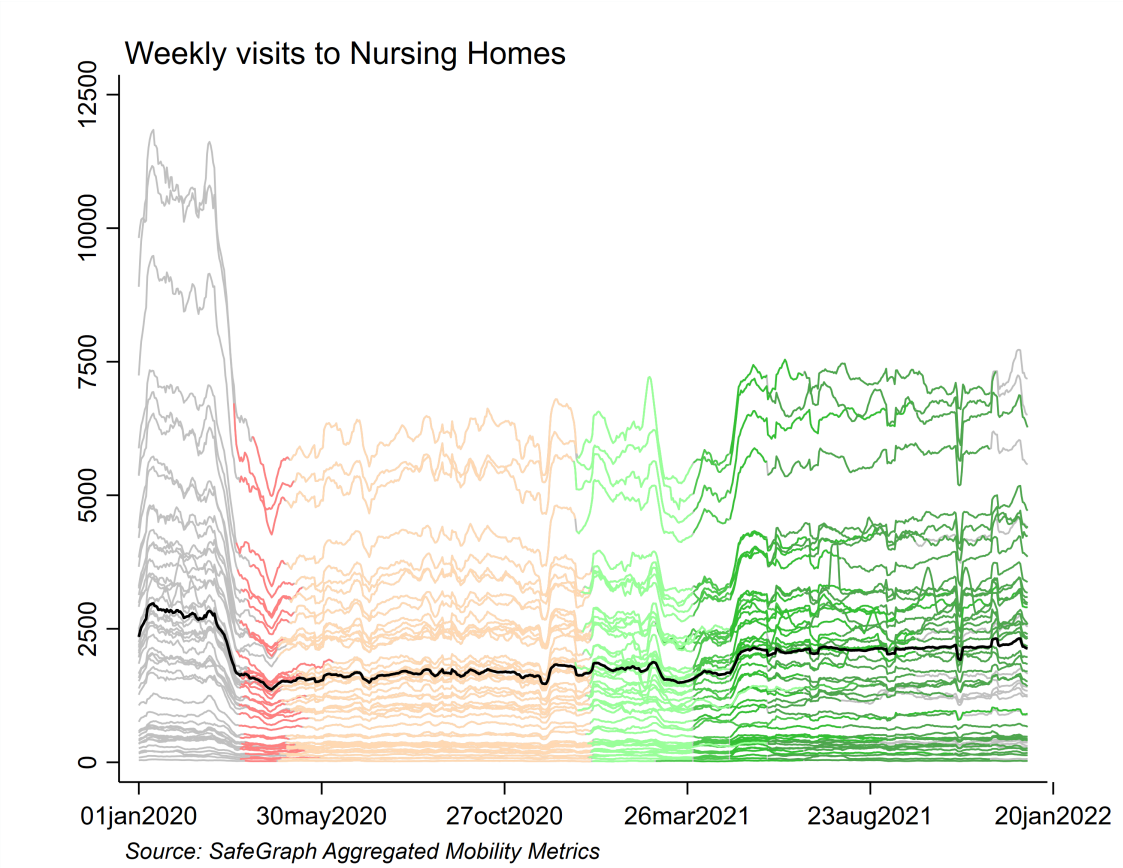
[2]Using McCarten et al. (2010)'s estimates, the half-year savings in healthcare costs from earlier ADRD diagnosis would be (1700/2) × 18,571=$15,785,589 in the first year of diagnosis. Using the estimates from the Alz (2018), the estimated half-year saving from an earlier and accurate ADRD diagnosis would be (14,000/2) × 18,571=$129,998,971.

complimentary analyses using the Health and Retirement Study to examine post-ADRD diagnosis health trajectories, including IADLs, ADLs, cognitive scores and institutionalization, of patients diagnosed at different levels of cognitive function.

This study has important policy implications. Our estimates provide evidence of pandemic induced disruptions/ delays in initial ADRD diagnosis, which may have subsequently delayed therapeutic interventions, life style changes and planning, put probable dementia patients at risk, and caused irreversible rapid disease progression. This study also provides evidence of some, but not complete, catch-up in delayed initial ADRD diagnosis following the COVID-19 vaccination roll and supports the broader public health impact of the COVID-19 vaccines.

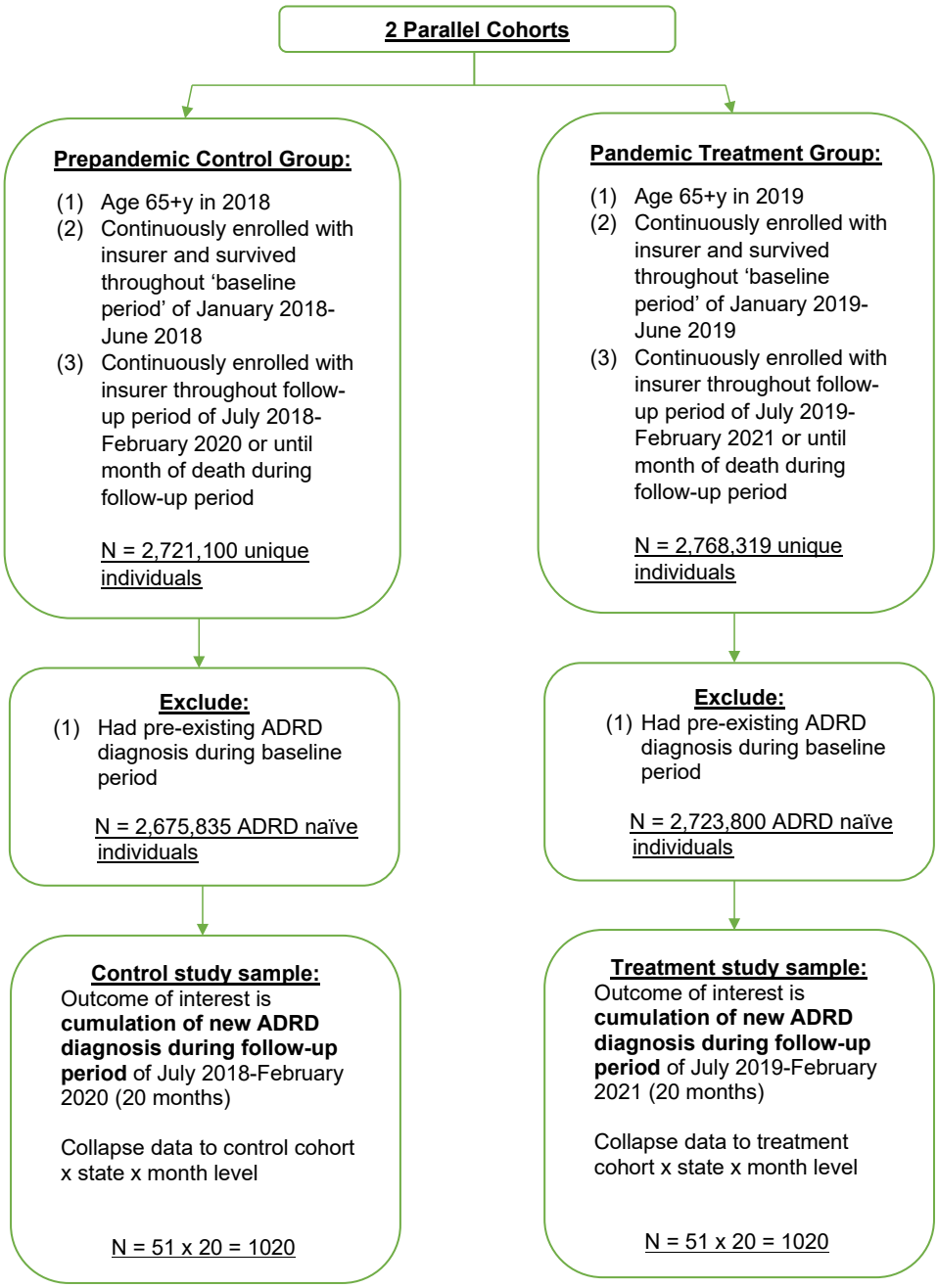
Tables and Figures

Figure 1: Mobility to nursing homes during the COVID-19 pandemic.



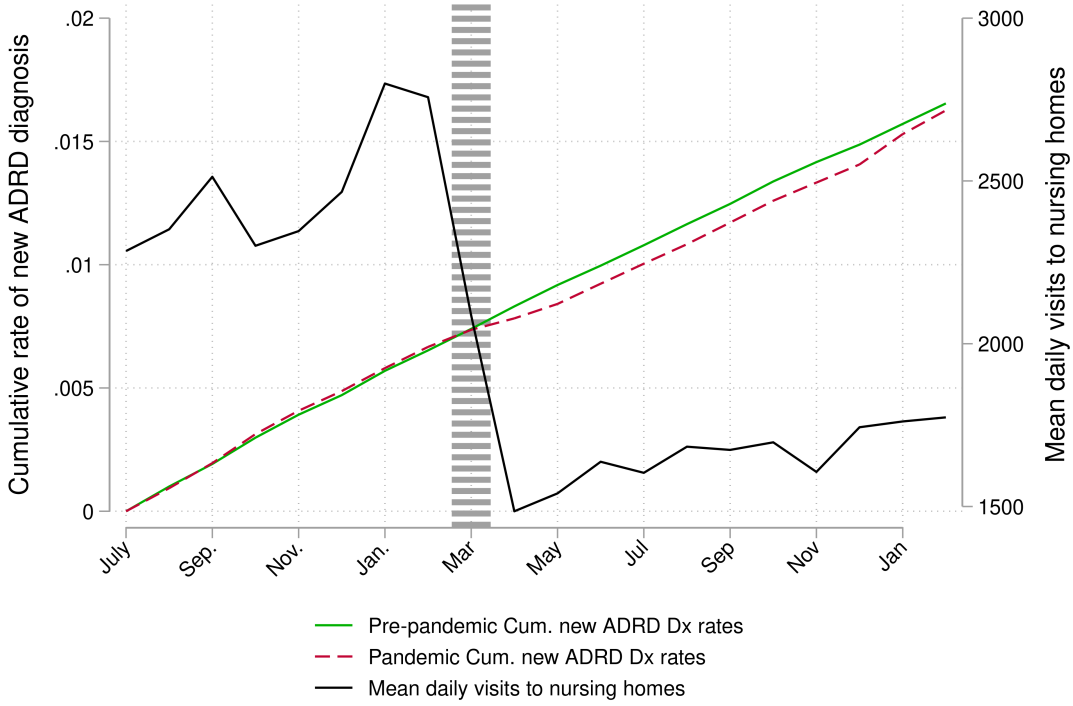
Notes. Author's calculation based on Places of Interest (POI) data from SafeGraph Aggregated Mobility Metrics. Smartphone mobility data are provided at the individual POI level, and nursing home locations are identified using 6-digit North American Industry Classification System (NAICS) code (the taxonomy developed by the US Census Bureau). The number of visits to the POI location each week are proxied by detected movement of smartphones. Each grey line represents a state, which turn red after the state implements stay-at-home orders, orange following official state re-opening, and green following state COVID-19 vaccination roll out. Progressively darker shades of green capture percentage of the state - 10%, 20%, 40% and 60% - vaccinated. The thick black line represents a "smoothed" 7 day moving average of the states capturing national trend.

Figure 2: ADRD naive pandemic treated and prepandemic control sample design.



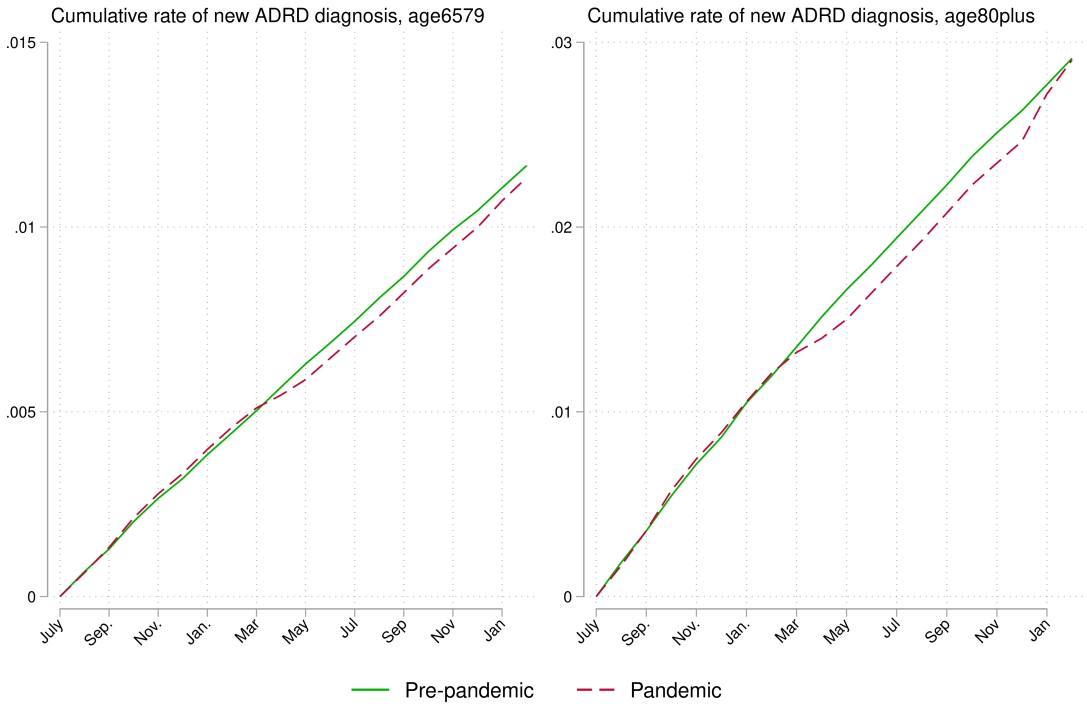
Notes. Sample design of 2 cohorts - prepandemic control and pandemic treated - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Patients were identified as ADRD naive if they were not observed to have an ADRD diagnosis during the baseline period, defined as the 6-month period prior to the observation window for each cohort, i.e. January - June 2018 for the prepandemic control cohort and January - June 2019 for the pandemic treatment cohort. A new ADRD diagnosis is the first observed ADRD diagnoses during the study period in an ADRD naive patient.

Figure 3: Trends in pandemic mobility to nursing homes and pre-pandemic and pandemic cumulative new Alzheimer's disease and related dementia diagnoses.



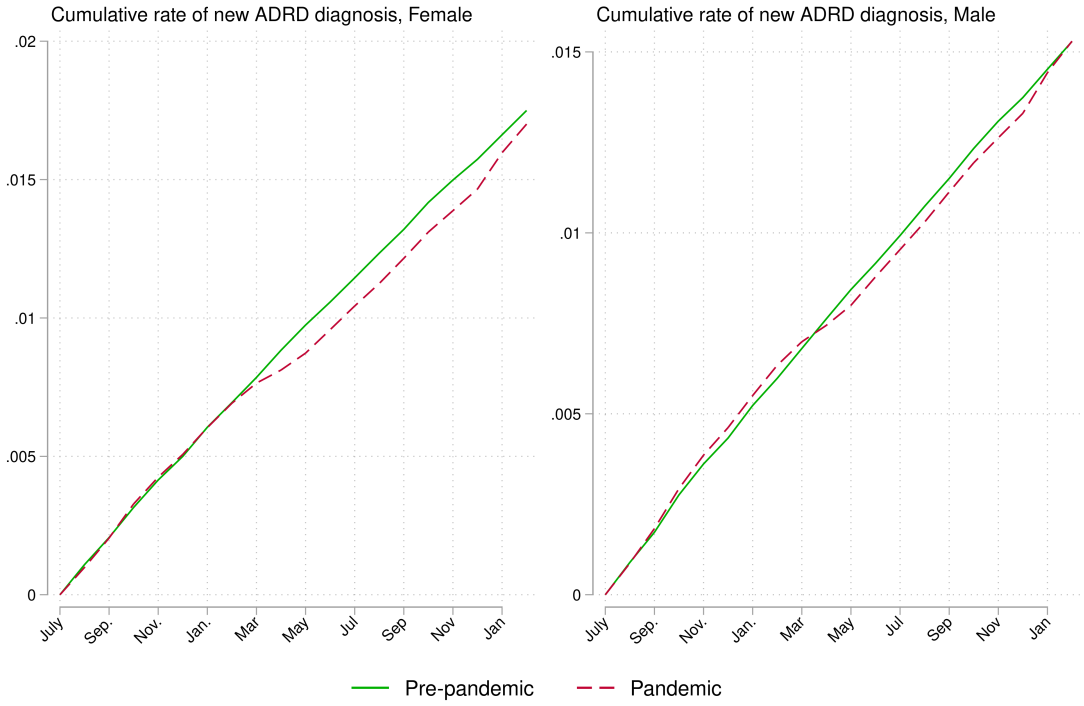
Notes. Author's calculations based on national cumulative rates of new Alzheimer's disease and related dementia (ADRD) diagnosis in 2 cohorts - prepandemic and pandemic - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Mean daily visits to nursing homes each, a proxy measure for social distancing, are calculated based on Places of Interest (POI) data from SafeGraph Aggregated Mobility Metrics. Smartphone mobility data are provided at the individual POI level, and nursing home locations are identified using 6-digit North American Industry Classification System (NAICS) code (the taxonomy developed by the US Census Bureau). The daily number of visits to the POI location are proxied by detected movement of smartphones. The solid black line represents a "smoothed" 7 day moving average of the states capturing national trend.

Figure 4: Trends in pre-pandemic and pandemic cumulative new Alzheimer's disease and related dementia diagnoses by age.



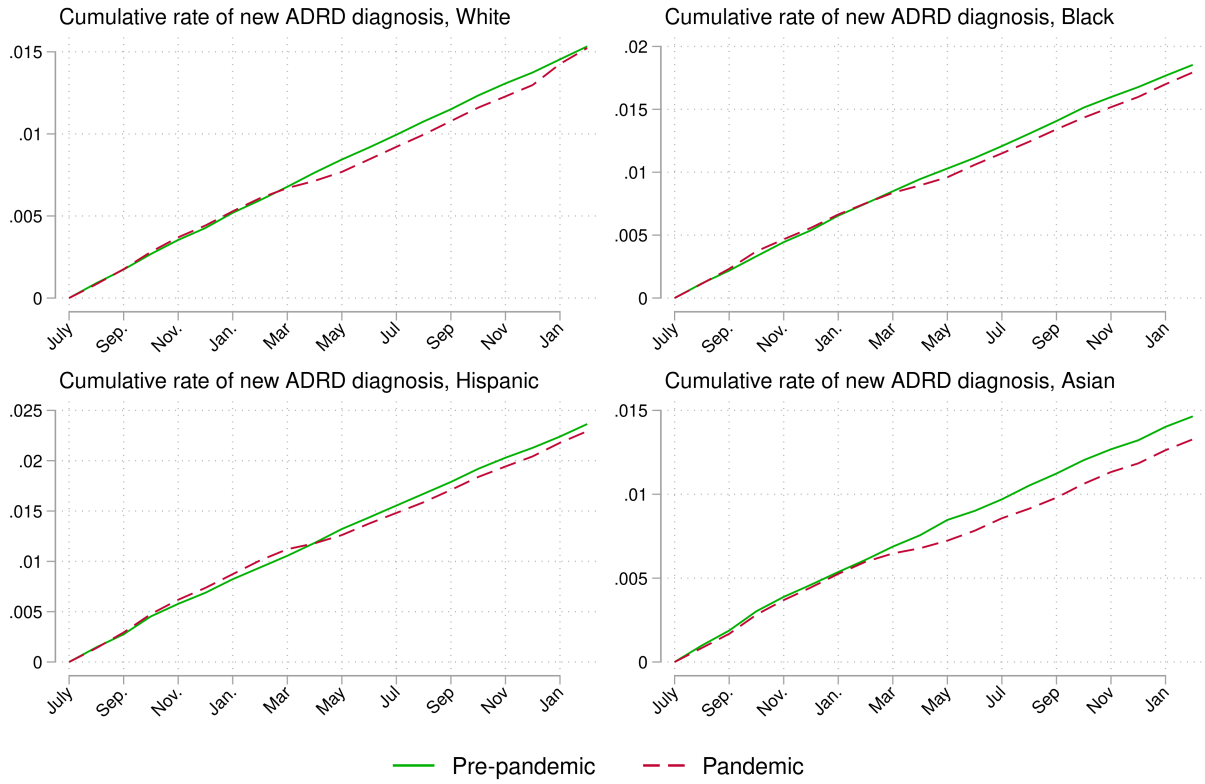
Notes. Author's calculations based on national cumulative rates of new Alzheimer's disease and related dementia (ADRD) diagnosis in 2 cohorts - prepandemic and pandemic - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Two age categories are considered - ages 65-79 years and ages 80+ years.

Figure 5: Trends in pre-pandemic and pandemic cumulative new Alzheimer's disease and related dementia diagnoses by gender.



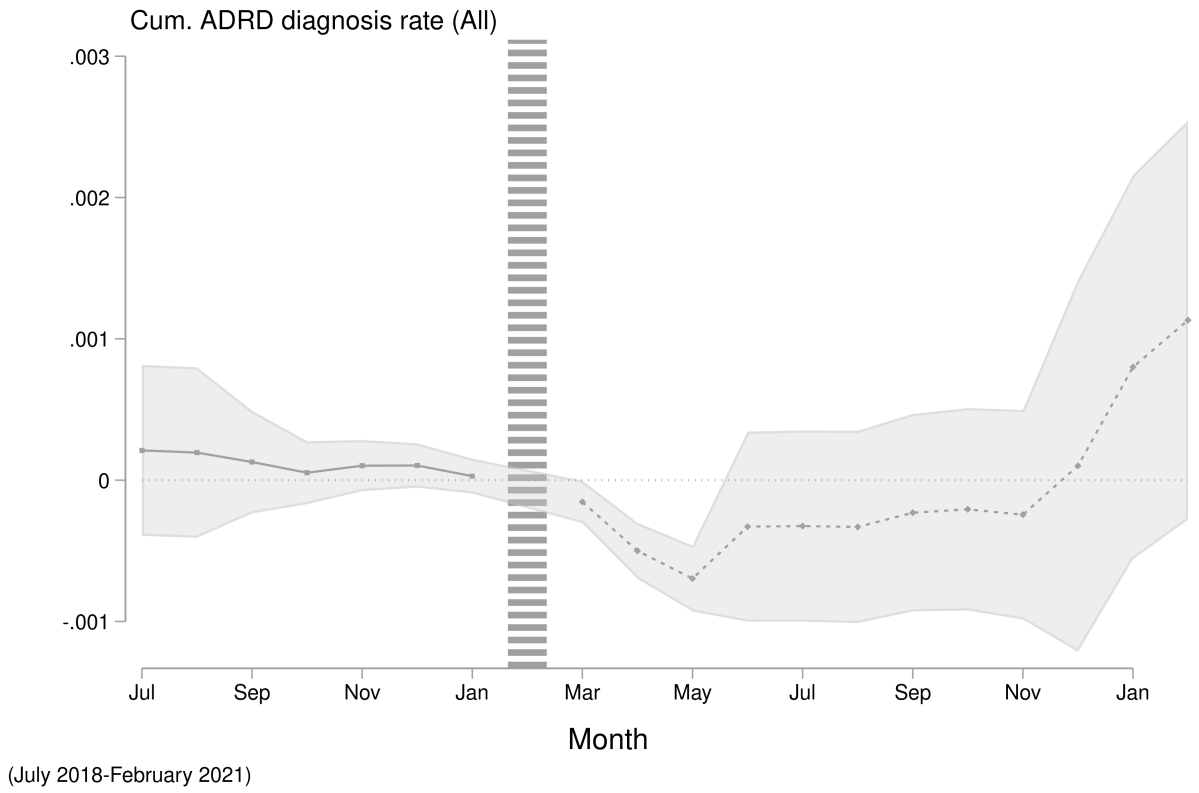
Notes. Author's calculations based on national cumulative rates of new Alzheimer's disease and related dementia (ADRD) diagnosis in 2 cohorts - prepandemic and pandemic - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort.

Figure 6: Trends in pre-pandemic and pandemic cumulative new Alzheimer's disease and related dementia diagnoses by race/ethnicity.



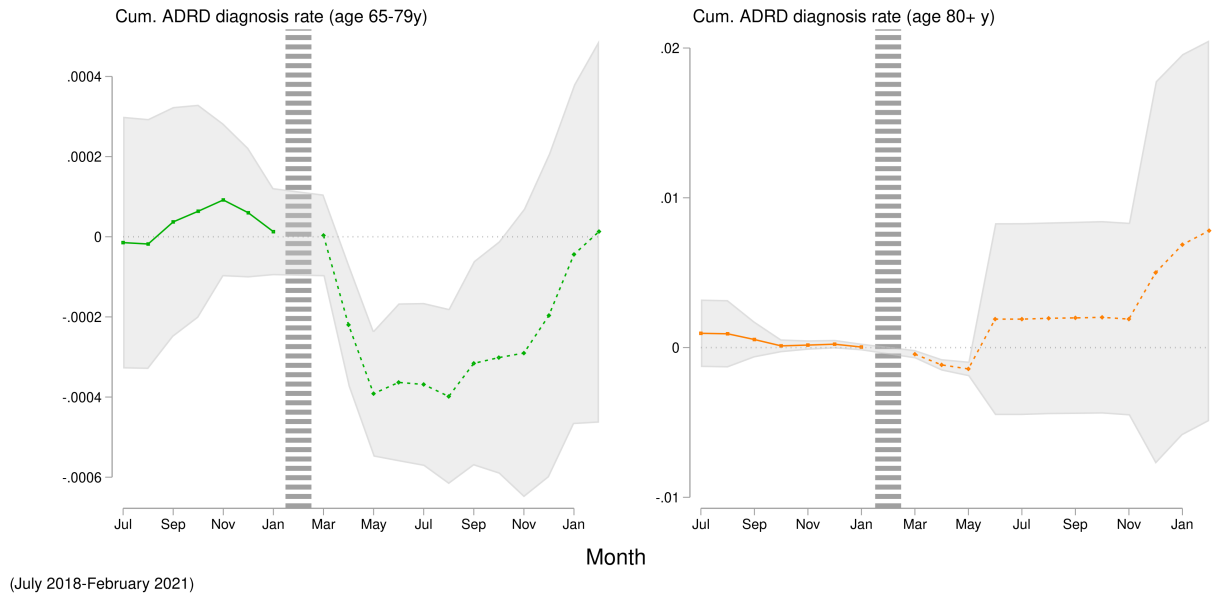
Notes. Author's calculations based on national cumulative rates of new Alzheimer's disease and related dementia (ADRD) diagnosis in 2 cohorts - prepandemic and pandemic - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Four available race/ethnity categories are considered - Asian, Black, Hispanic and White.

Figure 7: Event study regression results (Coefficients and 95% Confidence Intervals) of the impact of COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses.



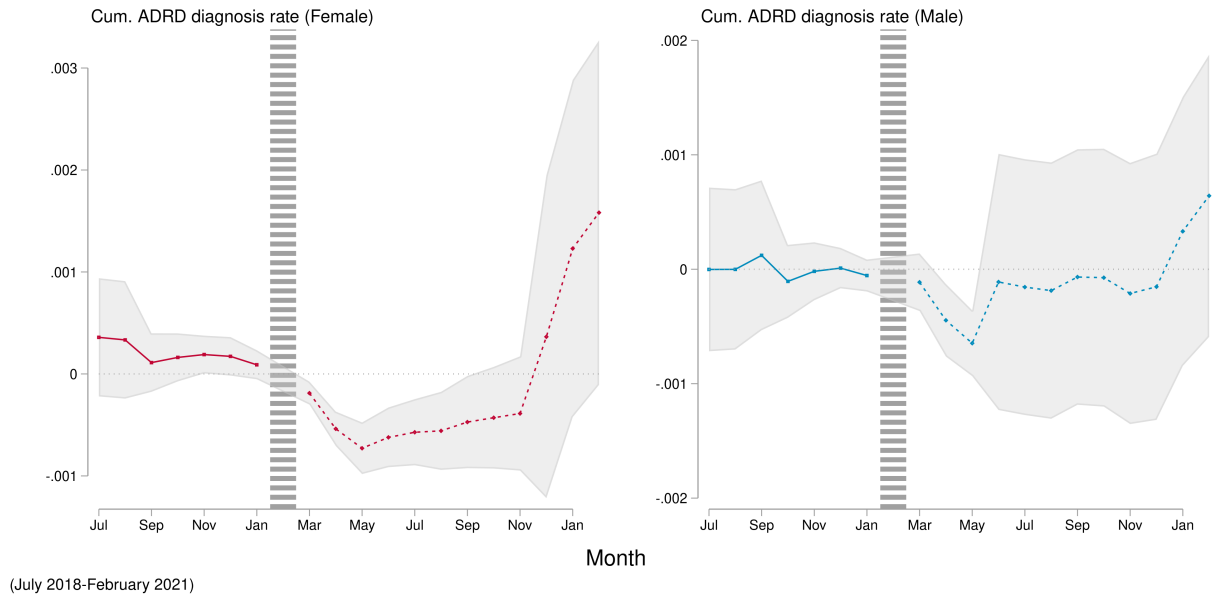
Notes. Author's calculations based on difference-in-difference event study estimation of cumulative rates of new Alzheimer's disease and related dementia (ADRD) in the pandemic cohort versus and prepandemic cohorts of ADRD naive patients, using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Unit of observation is cohort (prepandemic control or pandemic treated) x state x month. February 2020, the month prior to the onset of the COVID-19 pandemic is considered as the reference period. Regressions control for cohort, state and month-year fixed effects. Standard errors are clustered at state level. Panel presents event study estimates with the 95% confidence intervals.

Figure 8: Event study regression results (Coefficients and 95% Confidence Intervals) of the impact of COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses by age.



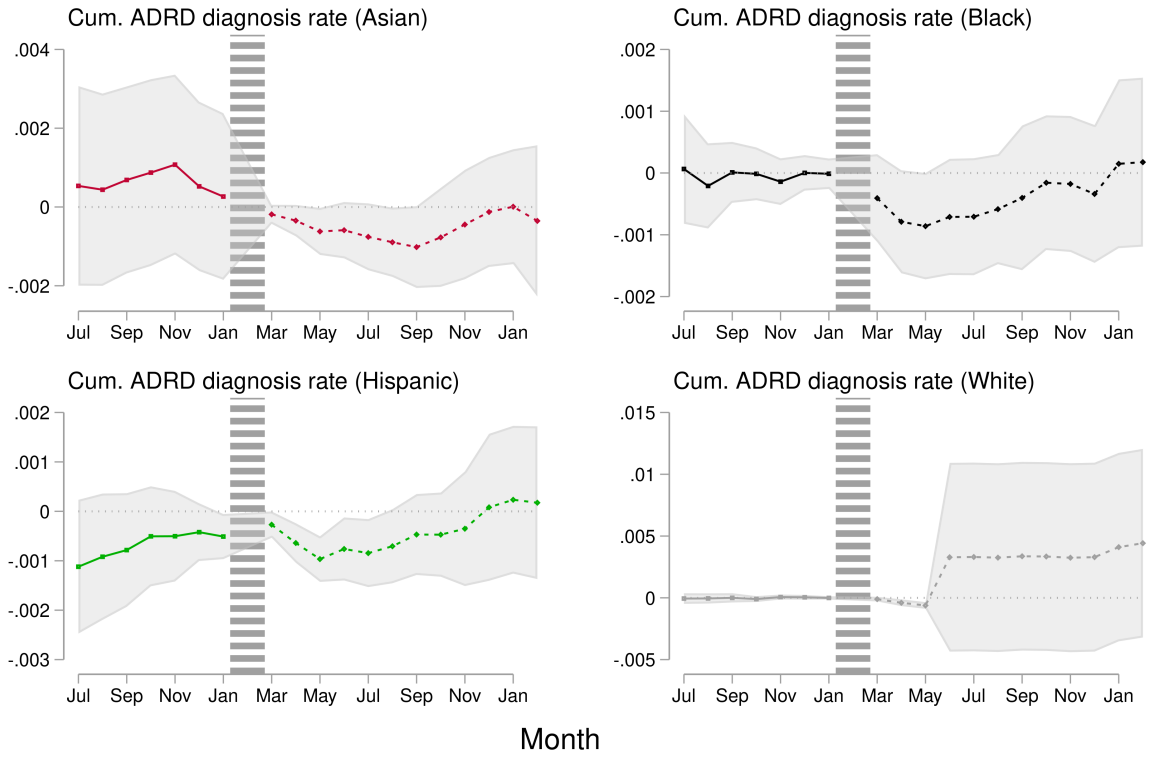
Notes. Author's calculations based on difference-in-difference event study estimation of cumulative rates of new Alzheimer's disease and related dementia (ADRD) in the pandemic cohort versus and prepandemic cohorts of ADRD naive patients, using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Unit of observation is cohort (prepandemic control or pandemic treated) x state x month. Stratified analyses uses subsets of samples by age categories (ages 65-79 years and 80+ years). February 2020, the month prior to the onset of the COVID-19 pandemic is considered as the reference period. Regressions control for cohort, state and month-year fixed effects. Standard errors are clustered at state level. Panel presents event study estimates with the 95% confidence intervals.

Figure 9: Event study regression results (Coefficients and 95% Confidence Intervals) of the impact of COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses by gender.



Notes. Author's calculations based on difference-in-difference event study estimation of cumulative rates of new Alzheimer's disease and related dementia (ADRD) in the pandemic cohort versus and prepandemic cohorts of ADRD naive patients, using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Unit of observation is cohort (prepandemic control or pandemic treated) x state x month. Stratified analyses uses subsets of samples by gender (female or male). February 2020, the month prior to the onset of the COVID-19 pandemic is considered as the reference period. Regressions control for cohort, state and month-year fixed effects. Standard errors are clustered at state level. Panel presents event study estimates with the 95% confidence intervals.

Figure 10: Event study regression results (Coefficients and 95% Confidence Intervals) of the impact of COVID-19 pandemic on cumulative new Alzheimer's disease and related dementia diagnoses by race/ethnicity.



Notes. Author's calculations based on difference-in-difference event study estimation of cumulative rates of new Alzheimer's disease and related dementia (ADRD) in the pandemic cohort versus and prepandemic cohorts of ADRD naive patients, using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Unit of observation is cohort (prepandemic control or pandemic treated) x state x month. Stratified analyses uses subsets of samples by race/ethnicity (Asian, Black, Hispanic or White). February 2020, the month prior to the onset of the COVID-19 pandemic is considered as the reference period. Regressions control for cohort, state and month-year fixed effects. Standard errors are clustered at state level. Panel presents event study estimates with the 95% confidence intervals.

Table 1: Descriptive characteristics of prepandemic and pandemic ADRD naive cohort.

	Pre-Pandemic Cohort		**Pandemic Cohort**	
	ALL	Received ADRD Dx during July 2018-Feb2020	ALL	Received ADRD Dx during July 2019-Feb2021
AGE (mean)	75.3	78.9	75.4	79.1
	(6.6)	(6.1)	(6.9)	(6.3)
Race (proportion)				
Asian	0.03	0.03	0.03	.03
	(0.18)	(.17)	(.18)	(.16)
Black	.11	.13	.11	.12
	(.32)	(.33)	(.31)	(.32)
Hispanic	.11	.16	.11	.16
	(.31)	(.36)	(.31)	(.36)
White	.70	.65	.70	.66
	(.46)	(.48)	(.46)	(.48)
Female (proportion)	.57	.60	.56	.59
	(.50)	(.49)	(.50)	(49)
Comorbidities (proportion)				
Congestive heart failure	.06	.07	.06	.07
	(.24)	(.26)	(.25)	(.26)
Coronary artery disease	.12	.14	.12	.14
	(.33)	(.35)	(.33)	(.35)
Cancer	.12	.11	.12	.11
	(.33)	(.31)	(.33)	(.32)
COPD	.08	.09	.08	.09
	(.28)	(.29)	(.28)	(.30)
Diabetes	.26	.29	.26	.29
	(.44)	(.45)	(.44)	(.45)
Stroke	.01	.02	.01	.02
	(.11)	(.14)	(.11)	(.14)
Hypertension	.51	.56	.51	.57
	(.50)	(.50)	(.50)	(.50)
Osteoarthritis	.12	.13	.12	.13
	(.32)	(.36)	(.32)	(.34)
Liver disease	.02	.01	.02	.01
	(.12)	(.11)	(.13)	(.11)
Renal disease	.10	.13	.11	.13
	(.31)	(.34)	(.32)	(.34)
Depression	.05	.10	.06	.14
	(.22)	(.29)	(.22)	(.35)
N	2,675,835	42,581	2,723,800	42,386

Note: Author's calculations based on 2 cohorts - prepandemic and pandemic - of ADRD naive patients using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Patients were identified as ADRD naive if they were not observed to have an ADRD diagnosis during the baseline period, defined as the 6-month period prior to the observation window for each cohort, i.e. January - June 2018 for the prepandemic control cohort and January - June 2019 for the pandemic treatment cohort. A new ADRD diagnosis is the first observed ADRD diagnoses during the study period in an ADRD naive patient.

Table 2: Changes in cumulative ADRD diagnosis rates associated with the pandemic.

	(1) All	(2) Age 65-79y	(3) Age 80+	(4) Female	(5) Male	(6) Asian	(7) Black	(8) Hispanic	(9) White
8 months prior to pandemic onset	0.000211	-0.0000146	0.000953	0.000359	-0.00000142	0.000536	0.0000651	-0.00112	-0.0000586
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
7 months prior to pandemic onset	0.000195	-0.0000180	0.000919	0.000334	-0.000000751	0.000439	-0.000209	-0.000919	-0.0000492
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
6 months prior to pandemic onset	0.000128	0.0000371	0.000538	0.000111	0.000122	0.000686	0.0000101	-0.000783	-0.000000202
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
5 months prior to pandemic onset	0.0000527	0.0000638	0.000113	0.000162	-0.000106	0.000873	-0.0000132	-0.000506	-0.0000998
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
4 months prior to pandemic onset	0.000103	0.0000919	0.000166	0.000190**	-0.0000178	0.00107	-0.000140	-0.000503	0.0000627
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
3 months prior to pandemic onset	0.000104	0.0000598	0.000226	0.000172*	0.0000100	0.000524	0.00000205	-0.000421	0.0000433
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
2 months prior to pandemic onset	0.0000284	0.0000127	0.0000362	0.0000899	-0.0000549	0.000265	-0.0000123	-0.000510**	-0.00000727
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Month of pandemic onset	-0.000154*	0.00000336	-0.000444***	-0.000188***	-0.000113	-0.000187	-0.000407	-0.000269*	-0.000104
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1 month post pandemic onset	-0.000500***	-0.000220***	-0.00116***	-0.000538***	-0.000446***	-0.000346*	-0.000789*	-0.000641***	-0.000398***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2 month post pandemic onset	-0.000696***	-0.000392***	-0.00143***	-0.000729***	-0.000646***	-0.000620**	-0.000861*	-0.000966***	-0.000615***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
3 month post pandemic onset	-0.000329	-0.000363***	0.00190	-0.000622***	-0.000111	-0.000589	-0.000711	-0.000762**	0.00328
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.004)
4 month post pandemic onset	-0.000325	-0.000369***	0.00190	-0.000572***	-0.000156	-0.000757*	-0.000708	-0.000845**	0.00331
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.004)
5 month post pandemic onset	-0.000331	-0.000398***	0.00195	-0.000558***	-0.000187	-0.000895*	-0.000585	-0.000706*	0.00325
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.004)
6 month post pandemic onset	-0.000230	-0.000316**	0.00198	-0.000472**	-0.0000677	-0.00102*	-0.000403	-0.000469	0.00337
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.004)
7 month post pandemic onset	-0.000206	-0.000302**	0.00202	-0.000429*	-0.0000735	-0.000771	-0.000157	-0.000471	0.00334
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.004)
8 month post pandemic onset	-0.000244	-0.000290	0.00190	-0.000388	-0.000212	-0.000446	-0.000177	-0.000352	0.00325
	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
9 month post pandemic onset	0.000102	-0.000196	0.00500	0.000364	-0.000153	-0.000126	-0.000339	0.0000812	0.00329
	(0.001)	(0.000)	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
10 month post pandemic onset	0.000800	-0.0000441	0.00687	0.00123	0.000332	0.00000726	0.000149	0.000234	0.00410
	(0.001)	(0.000)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
11 month post pandemic onset	0.00113	0.0000131	0.00780	0.00158*	0.000642	-0.000353	0.000176	0.000174	0.00442
	(0.001)	(0.000)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
Observations	2040	2040	2040	2040	2040	2040	2040	2040	2040
Baseline DV mean 2 months post March	0.00720	0.00476	0.0137	0.00747	0.00684	0.00683	0.00720	0.00717	0.00680
Baseline DV mean 6 months post March	0.00969	0.00661	0.0180	0.00999	0.00927	0.00881	0.00942	0.00957	0.00928
Baseline DV mean 11 months post March	0.0127	0.00881	0.0230	0.0130	0.0122	0.0113	0.0123	0.0128	0.0124
Effect size after 2 months	-9.7%	-8.2%	-10.4%	-9.8%	-9.5%	-9.1%	-11.9%	-13.5%	-9.1%
Effect size after 6 months	-2.4%	-4.8%	11.0%	-4.7%	-0.7%	-11.6%	-4.3%	-4.9%	36.3%
Effect size after 11 months	8.9%	0.2%	33.9%	12.1%	5.3%	-3.1%	1.4%	1.4%	35.7%

Note: Author's calculations based on difference-in-difference event study estimation of cumulative rates of new Alzheimer's disease and related dementia (ADRD) in the pandemic cohort versus and prepandemic cohorts of ADRD naive patients, using claims from a comprehensive commercial and Medicare Advantage claims database. Observation window is July 2018 to February 2020 for the prepandemic 'control' cohort and July 2019 to February 2021 for the pandemic 'control' cohort. Unit of observation is cohort (prepandemic control or pandemic treated) x state x month. Regressions control for cohort, state and month-year fixed effects. Standard errors are clustered at state level. Further stratified analyses considers subsets of samples stratified by age categories (ages 65-79 years and 80+ years in columns 2-3), gender (female and male in columns 4-5) and race/ethnicity (Asian, Black, Hispanic and White in columns 6-9) of patients. * p<0.05, ** p<0.01, *** p<0.001.

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