Influenza Vaccination Requirements in Nursing Homes: Impacts on Vaccination, Illness, and Mortality

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Abstract

Nursing home residents face both a high risk of influenza and influenza-related mortality. Influenza vaccinations can reduce these risks, but take-up remains suboptimal, in part because people may ignore the spillover benefit of positive externalities of vaccination on disease transmission. One approach that states have taken is to mandate influenza vaccination for nursing home residents and/or healthcare workers. This paper estimates the effect of such state policies on vaccination take-up and influenza-related diagnoses and deaths. Specifically, I estimate difference-in-difference models using data from the Long Term Care Minimum Data Set, Medicare claims, Nursing Home Compare data, and the National Vital Statistics System multiple cause of death files. I find that resident influenza vaccination requirements increase the probability of vaccination take-up by about 6% and decrease the probability of having an influenza-like illness diagnosis by roughly 20%. I also find evidence of external benefits of healthcare worker vaccination.

Keywords: externalities, infectious disease, influenza, vaccination

JEL codes: D62, H23, I12, I18

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1 Introduction

The annual burden of influenza is large in terms of illnesses, hospitalizations, deaths, and health-care expenditures. The Centers for Disease Control and Prevention (CDC) estimates that 9-45 million influenza-related illnesses and 140,000-810,000 influenza-related hospitalizations occur annually.[1] In 2017, influenza and pneumonia were the eighth leading cause of death in the U.S. (55,672 deaths).[2] Additionally, prior to 2020, influenza mortality exceeded that of any other infectious disease in the U.S. (CDC, 2017). Influenza is also very costly; the U.S. spends an estimated $10.4 billion on influenza-related medical visits each year (Molinari et al., 2007).

Older people are at greater risk of influenza and influenza-related complications.[3] Up to 70% of influenza-related hospitalizations and up to 85% of influenza-related deaths occur among people 65 years and older (CDC, 2019b). Older people are at higher risk because the immune system weakens with age. The susceptibility of older people to infectious diseases has been further highlighted in recent events; in the United States, roughly 8 out of 10 deaths caused by COVID-19 have been among adults 65 years and older (CDC, 2020a).

Furthermore, residents in long-term care facilities face an even greater risk of acquiring influenza due to their weakened immune systems, comorbidities, close living arrangements, shared caregivers, and exposure to visitors (Strausbaugh et al., 2003; Pop-Vicas and Gravenstein, 2011). Importantly, residents are in long-term care facilities because they require personal or medical assistance beyond what they can receive at home. Consequently, they are more frail than community dwelling older people. Mortality rates of nursing home residents during a seasonal influenza outbreak can exceed 5% (Kingston and Wright, 2002). This is concerning given that there are approximately 1.3 million individuals living in nursing homes and 84% of these residents are 65 years and older (CDC, 2019).

The trajectory of pandemics, epidemics, and seasonal illnesses, such as influenza, are dependent on the population's protective behavioral response to disease prevalence (Philipson, 2000; Perrings et al., 2014; Hauck, 2018). One way to reduce disease prevalence is through vaccination. The ultimate goal of widespread vaccination is to achieve a threshold of population immunity ("herd immunity") such that a disease can no longer persist. Since 2011, the CDC's Advisory Com-

[1] Numerous factors contribute to the wide range of estimates, such as the circulating viruses, timing of the influenza season, effectiveness of influenza vaccines, and vaccination rate, among others.

[2] Influenza is infrequently documented on death certificates. Consequently, influenza deaths are typically grouped with pneumonia deaths. This is discussed further in Section 3.6.

[3] Common influenza-related complications include pneumonia, bronchitis, sinus and ear infections, sepsis, and heart attacks, among others.

mittee on Immunization Practices has recommended annual influenza vaccination for all persons who are at least six months old and who do not have contraindications.[4] However, individuals may have little incentive to vaccinate if they reap the benefits of herd immunity without any cost. Since people do not fully internalize the benefit of vaccination, government interventions such as mandates and Pigouvian subsidies have been implemented to address the under-consumption of vaccines relative to the socially optimal level (Sloan, 2012).

Mandatory vaccinations are one policy tool to reduce the burden of infectious diseases. Public policy has largely focused on mandatory vaccinations for children rather than for adults.[5] Adult vaccination, however, is important because adults 65 years and older and those with weakened immune systems are at high risk of serious influenza-related complications.[6] For the 2017-18 influenza season, vaccinations prevented an estimated 7 million illnesses, 3 million outpatient medical visits, 109,000 hospitalizations, and 8,000 respiratory and circulatory deaths (Rolfes et al., 2019). Yet, nationally, only 37% of people 18 years and older and 59% of people 65 years and older received an influenza vaccination during the 2017-18 season (CDC, 2019a). These rates fall below target vaccination rates.[7,8] Further, vaccination rates varied considerably across states, ranging from 29% in Louisiana to 46% in West Virginia (CDC, 2019c). Vaccination rates, however, are higher in nursing homes; for the 2017-18 season, an estimated 73% of nursing home residents were vaccinated, ranging from 49% in Nebraska to 89% in South Dakota (CDC, 2019d). To address the under-consumption of vaccinations, states have implemented laws requiring influenza vaccination in various settings such as hospitals, ambulatory care, and long-term care facilities. The latter are the focus of this paper.

This research provides causal estimates of the impacts of state-level influenza vaccination requirements for residents and healthcare workers in long-term care facilities on influenza vac-

[4]A contraindication is a condition that puts the vaccine recipient at risk for a serious adverse reaction. Such conditions include life threatening allergies to the flu vaccine or any ingredient in the vaccine, history of Guillain-Barré Syndrome, pregnancy during the first trimester, and various states of immunosuppression.

[5]For example, immunizations are required for children and adolescents to attend school. In general, state vaccination requirements for school children not only apply to children attending public schools but also to those attending private schools and day care. Additionally, programs such as the Vaccines for Children Program and Section 317 of the Public Health Services Act subsidize childhood vaccinations.

[6]High-risk groups include adults 65 years and older, pregnant women, young children, children with neurological conditions, and those with or a history of asthma, heart disease or stroke, diabetes, HIV/AIDS, and cancer.

[7]In 2010, the U.S. Department of Health and Human Services launched an initiative called Healthy People 2020, which set target vaccination rates at 80% for adults 18-64 and 90% for high-risk adults 18-64 and adults 65 years and older.

[8]A survey conducted by the University of Chicago's National Opinion Research Center (NORC) found that for the 2019-20 season, 37% of adults reported that they did not intend to receive an influenza vaccination and the most commonly cited reasons were concerns about the side effects from the vaccine and efficacy of the vaccine (NORC, 2019).

cination take-up and health outcomes of residents (i.e., influenza-related illnesses and deaths). Ex ante, the effects of vaccination requirements on vaccination take-up may be minimal since influenza vaccination rates in long-term care setting settings are relatively high compared to those in community settings. The net effects of vaccination requirements on health outcomes are ambiguous. On the one hand, increases in vaccination take-up could decrease influenza-related diagnoses and deaths. On the other hand, vaccination may crowd out other protective behaviors such as hand washing or cause facilities to relax other infection control measures that could negatively affect health outcomes. To estimate these effects of the requirements on vaccinations and health outcomes, I use difference-in-differences methods using "exogenous" variation from the implementation of state-level vaccination requirements. I use administrative micro data from the Long Term Care Minimum Data Set (MDS) and claims data from Medicare fee-for-service beneficiaries, as well as Nursing Home Compare data and the National Vital Statistics System (NVSS) multiple cause of death files. These data provide detailed information surrounding the health care utilization and health outcomes of nursing home residents.

I find that resident influenza vaccination requirements increase vaccination take-up by 4-5 percentage points (about 6%) and decrease influenza-related diagnoses and deaths by 4-5 percentage points (approximately 20%) and 0.1-0.2 percentage points (about 10%), respectively. Additionally, I find some evidence of an external benefit of healthcare worker vaccination requirements to nursing home residents. These results speak broadly to the question of how government interventions can reduce the spread of infectious disease and improve public health.

This research contributes to three strands of literature. First, this paper relates to the literature on economic epidemiology and the economics of infectious disease. The field of economic epidemiology and the economics of infectious disease applies concepts from economics like behavior under uncertainty and externalities to provide insight on how people respond to the risk of infectious diseases. Vaccination is a large focus of this literature as they are an effective disease mitigation tool, but private (individual) vaccination take-up decisions are based on complex factors such as disease prevalence. Several studies find that the demand for vaccination is an increasing function of disease prevalence (Philipson, 1996; Geoffard and Philipson, 1997; Boulier et al., 2007; Oster, 2018; Schaller et al., 2019). However, beyond a certain threshold, the marginal benefit of vaccinating additional people decreases (Boulier et al., 2007; Ward, 2014) and approaches zero when herd immunity is achieved (Sloan, 2012). Importantly, the benefit accrues to both people who have been vaccinated as well as those who are not vaccinated. Additionally, this literature examines how policies like subsidies and mandates can improve public welfare (e.g. Philipson, 2000; Perrings et al., 2014; Hauck, 2018). My paper complements the current literature on vaccination take-up decisions from a policy angle by examining the extent to which vaccination requirement policies can increase vaccination take-up.

Second, this paper contributes to the emerging literature on the impacts of vaccination requirements and campaigns. Typically, these requirements and campaigns have targeted two groups: children and healthcare workers. For the former, vaccination requirements for children have been effective in increasing vaccination rates for hepatitis A (Lawler, 2017), varicella (Abrevaya and Mulligan, 2011), and tetanus, diptheria, and pertussis (Carpenter and Lawler, 2019). Vaccination campaigns have also been effective in increasing influenza and tuberculosis vaccination take-up (Loeb et al., 2010; Ward, 2014; Butikofer and Salvanes, 2018). For healthcare workers, however, there is mixed evidence regarding the effectiveness of healthcare vaccination requirements on patient outcomes (De Serres et al., 2017; Thomas et al., 2016).[9] Most similar to this research, White (2020) estimates the effects of county-level influenza vaccination requirements for healthcare workers in California on outcomes measured at the hospital level. White (2020) finds that these requirements increased hospital worker vaccination take-up by 10.3 percentage points and decreased influenza inpatient admissions by 20%.[10] This paper builds upon this literature by providing causal estimates of the impacts of influenza vaccination requirements for residents and healthcare workers in the context of nursing homes. This setting is of particular interest for two reasons. First, residents are at high-risk of influenza and severe influenza-related complications due to their age and health needs. Second, healthcare workers in long-term care settings have lower influenza vaccination coverage (68%) than healthcare workers in other healthcare settings such as hospitals (95%), ambulatory care or physician office (80%), and other clinical settings[11] (88%) (Black et al., 2018; CDC, 2019e).

[9]Although studies find that healthcare worker vaccination requirements are effective in increasing vaccination rates, there is limited evidence that this translates to improvements in patient outcomes. De Serres et al. (2017) and Thomas et al. (2016) review four cluster randomized controlled trials of healthcare worker influenza vaccination in long-term care facilities. They conclude that these studies find implausibly large reductions in patient risk to healthcare worker vaccination and that these studies violate the principle of dilution (reductions for less-specific outcomes such as all-cause mortality exceed reductions from influenza-like illness which exceed reductions for laboratory confirmed influenza). They also critique these studies for failing to include information about co-interventions such as hand-washing, wearing face masks, and recommending sick workers to stay home when sick, among others.

[10]Prior to the implementation of vaccination requirements for healthcare workers, the mean vaccination rate for hospital workers in treatment group hospitals was 74.0%, and the mean number of influenza diagnoses in inpatient admissions (at the hospital-flu year level) was about 22. Though not discussed in the paper, I suspect the reason the vaccination rate was not 100% after the implementation of the requirement was likely due to allowable exemptions and variation in compliance.

[11]E.g., dental clinic, laboratory, emergency medical services.

Third, this research extends the literature surrounding the economic impacts of influenza infection. People 65 years and older account for the majority of influenza cases annually but can also spread the virus to younger people, which has health and labor market implications. In-utero exposure to both pandemic and seasonal influenza has negative impacts on childhood health such as low birth weight and premature birth (Almond, 2006; Currie and Schwandt, 2013), adult health such as kidney disease, diabetes, and respiratory problems (Almond and Mazumder, 2005; Lin and Liu, 2014), and later-life outcomes such as earnings reductions, greater welfare dependence, increased rates of disability, and lower socioeconomic status (Almond and Mazumder, 2005; Schwandt, 2018). While I do not directly examine the economic impacts of influenza infection, this existing literature suggests that the estimated benefits of vaccination requirements are likely to be a lower bound of the true benefits of these requirements. Averted diagnoses and deaths not only decrease health care spending, but can also generate positive externalities related to health and labor market outcomes.

This paper proceeds as follows. Section 2 provides background information. Section 3 describes the data. Section 4 outlines the empirical strategies. Section 5 presents the results. Section 6 concludes.

2 Background

In this section, I provide details on the institutional features of nursing homes, vaccinations, and vaccination policies.

2.1 Nursing Homes

Long-term care facilities provide nursing, rehabilitative, and social services for people who are unable to live independently. For the purpose of this paper, I focus on patients in nursing homes since these types of patients are observable in my data. The term "nursing home" often includes both nursing facilities and SNFs. Commonly, facilities offer both activities of daily living assistance, which is emblematic of nursing facilities, as well as medically necessary therapy, which is associated with SNFs. The main differences between the two types of facilities are the time a resident is expected to reside in the facility and the main payer (Medicare or Medicaid). In 2016, there were over 15,600 nursing homes, and these facilities provided care to over 1.3 million residents (CDC, 2019). Roughly two-thirds of nursing home residents are female and three-quarters of residents are over age 65 (CDC, 2016).

2.2 Vaccinations

Influenza is a potentially serious illness affecting millions each year, but vaccines reduce the risk of illness. The vaccine protects against either three or four viruses: influenza A (H1N1 and H3N2) and one or two strains of the influenza B virus.[12] Containing either an inactive or weakened form of the influenza viruses, the vaccine triggers the immune system to produce antibodies that protect against influenza viruses. When a vaccinated person comes in contact with an influenza virus, the body can quickly produce antibodies to protect against the virus.

Multiple factors influence vaccine effectiveness. First, effectiveness depends on the characteristics, such as age and health, of the person being vaccinated. The vaccine is less effective for those with weakened immune systems due to age or underlying health conditions. Despite the weakened immune response of older people, the vaccine still confers protection and reduces the severity of illness if infected.[13] Second, effectiveness can vary from season to season depending on how well matched the influenza vaccine is to the circulating influenza viruses. Prior to each flu season, researchers predict which influenza viruses are mostly likely to circulate and cause illness. The vaccine is then reformulated to adjust for genetic changes in the influenza virus. On average, the vaccine reduces the risk of influenza by 40% to 60% when the vaccine is well-matched to circulating viruses (CDC, 2020). The vaccine offers fewer protections against influenza when the vaccine is not well matched to the circulating virus. The effectiveness of the vaccine also varies by the type of circulating virus; the vaccine is more effective in reducing illness caused by influenza A(H1N1) and influenza B while protection against influenza A(H3N2) has been less consistent (CDC, 2020).[14]

Although vaccinations are an effective protective behavior that have reduced the burden of infectious disease, they impose both private costs and benefits to the vaccinated. Private vaccination costs include monetary (e.g. potential copay, transportation) and non-monetary (e.g. inconve-

[12]The quadrivalent vaccine is the standard vaccine and offers broader protection (relative to trivalent vaccine) since it includes both influenza B viruses. The trivalent vaccine is a high dose vaccine that contains a higher amount of antigen to produce a stronger immune response. The trivalent vaccine is specifically designed for people 65 years and older.

[13]Some people who receive the influenza vaccine still contract the illness. Studies show, however, reductions in influenza deaths, intensive care unit admissions, length of stay, and overall duration of hospital stay for vaccinated people relative to those who had not been vaccinated (CDC, 2020).

[14]Influenza A(H3N2) exhibits antigenic change more frequently than influenza A(H1N1) and influenza B viruses. As a result, the composition of the influenza A(H3N2) component of the vaccine is less likely to resemble the circulating influenza A(H3N2) virus.

nience, discomfort, potential side-effects) costs.[15] The benefits of vaccination include both private and external benefits. A vaccinated person receives a private benefit in the form of reduced risk of illness and related hospitalization. In the event of illness, vaccination reduces the severity of the illness. Vaccinations also generate external benefits by protecting people who have not been vaccinated and are a textbook example of "positive externalities".[16] Such external benefit relates to the reduced risk of spreading an illness to others who have not been vaccinated. When more people are vaccinated (and are thus uninfected and resistant or immune to illness), a virus is less likely to spread and cause illness among both vaccinated and un-vaccinated people. Despite these external benefits, we assume that people make their calculation about the private benefits and costs but do not take into consideration the benefits to others. Consequently, because people do not fully internalize the benefit to others, the demand for vaccines falls below the socially optimal level absent government interventions such as subsidies and mandates.

2.3 Vaccination Requirements

Currently, 32 states have laws requiring influenza vaccination for residents and 25 states have laws requiring vaccination for healthcare workers in long-term care facilities (CDC, 2018a). The content of state laws was collected from the CDC Public Health Law Program's "Menu of State Long-Term Care Facility Influenza Vaccination Laws". This document contains the legal citation of the statute or regulation documenting vaccination requirements for residents and healthcare workers in long-term care facilities. Tables 1 and 2 document the year of policy implementation for residents and healthcare workers, respectively, which were determined through a process of searching legal databases such as Nexis Uni and HeinOnline, as well as independent research.

Across states there is heterogeneity in the stringency of the vaccination requirements. The majority of these requirements pertain to either all long-term care facilities or nursing homes, specifically. There are two types of vaccination requirements: administrative offer and administrative ensure. States with administrative requirements to offer vaccination must offer vaccination to residents and/or healthcare workers, while states with administrative requirements to ensure vaccination must provide proof of vaccination or documentation of exemption (Lindley et al., 2007). All states with vaccination requirements allow medical exemptions, and some states also

[15] Under the Affordable Care Act, health insurers are required to provide all federally recommended vaccines at no cost. Medicare Part B covers vaccination for seasonal influenza, hepatitis B, and pneumococcal disease with no copay or deductible.

[16] See Gruber (2005), Bhattacharya et al. (2013), Folland et al. (2016), and Besanko and Braeutigam (2020).

allow religious and philosophical exemptions. Additionally, the population of healthcare workers subject to vaccination requirements varies across states; some states require vaccination for all healthcare workers while others only require vaccination for workers with occupational exposure or direct patient contact. These requirement types and exemptions are also documented in Tables 1 and 2 for residents and healthcare workers, respectively.

3 Data

These research uses several data sources: Long Term Care Minimum Data Set, Medicare claims, Nursing Home Compare, and National Vital Statistics System multiple cause of death mortality files. This section describes each of these data sources and then the construction and measurement of study outcomes.

3.1 Long Term Care Minimum Data Set

The Long Term Care Minimum Data Set (MDS) is a federally mandated health screening and assessment tool used for all residents in Medicare and Medicaid certified nursing homes. The assessment is administered at admission, discharge, and three month intervals during the stay (or more frequently if the resident experiences a major health status change). The MDS provides a comprehensive clinical assessment of each resident's functional capabilities and health conditions.[17] Importantly, the assessment documents whether a resident received an influenza vaccination in the facility and date of vaccination. This study uses MDS data from 2011 through 2014 for a sample of Medicare fee-for-service beneficiaries. Appendix A further discusses the sample of beneficiaries included in this data. The MDS data capture assessments for approximately 3.6 million unique individuals between 2011 and 2014 and contain approximately 7.7 to 8.5 million assessments per year.

3.2 Medicare Claims

Medicare claims capture claims submitted by providers as well as from inpatient and outpatient facilities for Medicare beneficiaries. While the primary purpose of Medicare claims is to provide reimbursement for medical services, they also provide detailed information about the diagnoses

[17] For example, the data include detailed information about resource utilization group code, measures of clinical status, physical functioning, psychological status, and diagnoses and medications.

received and procedures performed on a patient. This study uses Medicare claims from 2011 through 2014.

3.3 Nursing Home Compare

Nursing Home Compare contains information about every Medicare and Medicaid certified nursing home in the country. This includes information about the quality of nursing homes, which is captured by star ratings, inspection results (health, fire safety, and emergency preparedness), and penalties, as well as staffing and resident quality of care measures.[18] Among the resident quality of care measures are the percentage of long-stay and short-stay residents who received an influenza vaccine for the current flu season.[19,20] Long- and short-stay residents differ in their underlying health conditions and reasons for being in the nursing home. Long-stay residents typically receive residential care and they enter a nursing home because they are no longer able to care for themselves at home. In contrast, short-stay patients typically receive post acute or rehabilitative care and their goal is to return to their previous setting. This study uses Nursing Home Compare data from 2006 through 2017.

3.4 National Vital Statistics System (NVSS) Multiple Cause of Death Files

These data contain individual death certificate records for the full census of U.S. deaths. The data contain detailed information about the death, including underlying cause of death, twenty additional multiple causes of death, and place of death. The restricted version additionally includes geographic identifiers such as state and county of residence. This study uses multiple cause of death files from 1999 through 2016.

3.5 Construction of Outcomes

The outcomes of interest include: influenza related vaccination, illnesses, and deaths. Importantly, I only observe outcomes for nursing home residents. Although healthcare worker vaccination requirements are of interest, I do not observe outcomes among healthcare workers. Appendix Appendix Table A1 summarizes the data sources, years available, and level of aggregation.

[18] Additionally, Nursing Home Compare captures whether nursing home participates in Medicare, Medicaid, or both, whether the nursing home is located within a hospital, and the type of ownership, among other information.

[19] Long-stay residents are those who had a stay of 101 days or more. Short-stay residents are those who had a stay of 100 days or less or are covered under the Medicare Part A Skilled Nursing Facility benefit.

[20] The percentage of residents who received the seasonal influenza vaccine are derived from the MDS.

3.5.1 Vaccination

The first-stage outcome - influenza vaccination - is derived at both the resident- and facility-level. At the resident-level, vaccinations are identified using both the MDS and Medicare claims. The MDS captures whether the resident received an influenza vaccination at the facility and date of vaccination. Vaccination prior to nursing home admission or not captured in the MDS are observable in the Medicare claims. Specifically, influenza vaccination is identified using diagnosis and procedure codes from the Medicare inpatient, outpatient, and carrier files (see Appendix Table A2 for diagnosis and procedure codes and descriptions). A resident is considered to have been vaccinated if either an MDS assessment or Medicare claim indicates influenza vaccination in a given calendar-quarter. Additionally, a resident is considered to have been vaccinated in all subsequent quarters within a flu season after the earliest influenza vaccination date. For example, if a resident received a influenza vaccine in November 2011 (2011 Q4), the resident is considered to be vaccinated in the remaining quarters of the 2011-12 influenza season (2012 Q1 through Q2 or Q3).[21] At the facility-level, Nursing Home Compare reports the percent of short- and long-stay residents who needed and received the influenza vaccine for the current flu season in a given calendar-quarter.[22]

3.5.2 Illnesses

Influenza and influenza-like illness (ILI) diagnoses are derived using Medicare claims at the resident-level. Although diagnostic codes specific to influenza are available in Medicare claims, these under count the occurrence of influenza, particularly in outpatient settings.[23] Consequently, I also consider the outcome of influenza-like-illness (ILI), which is defined by having a fever (temperature $\geq$ 100°F) and cough and/or sore throat with no other known cause of illness other than influenza. The outcome is a binary indicator for each influenza-related diagnosis. The variable is equal to one if a resident has a given diagnosis in any setting (inpatient admission or outpatient visit) using both primary and secondary diagnostic codes (see Appendix Table A3 for ICD codes

[21] This measurement of vaccination assumes that vaccination protection lasts for the duration of the flu season. Typically, protection from the vaccine lasts for at least six months, so people vaccinated at the start of the flu season (which begins around October) will have protection for the duration of the flu season. Protection, however, declines over time due to decreasing antibody levels and changes in the circulating influenza viruses (Immunization Action Coalition, 2020).

[22] However, Nursing Home Compare suppresses quality measure scores for small nursing homes (<30 residents for long stay measures and <20 residents for short stay measures).

[23] An influenza diagnosis requires a lab-confirmed test for influenza, which is expensive and typically only matters for inpatient admissions since the diagnosis can affect how patients are assigned to hospital rooms.

and descriptions).

3.5.3 Deaths

At the resident-level, influenza-related deaths are identified using Medicare claims and enrollment files. Deaths are identified using date of death in the Medicare enrollment files. Deaths occurring within 30 days of an influenza or ILI event are characterized as an influenza-related death.[24]

Additionally, I supplement Medicare claims and enrollment files with the restricted-use version of the multiple cause of death mortality files from the National Vital Statistics System (NVSS) to derive state-level influenza-related mortality. Because influenza is rarely documented on death certificates, I identify influenza and pneumonia deaths since this has the highest level of specificity (rather than influenza-specific mortality).[25] However, influenza/pneumonia deaths can still exclude deaths related to influenza illness. In robustness checks, I also explore deaths with any respiratory or circulatory diagnosis.[26]

3.6 Summary Statistics

Table 3 shows summary statistics of the outcome variables, averaged across all resident-quarters and derived from the MDS and Medicare claims data. Approximately 72% of residents received an influenza vaccination. This is similar to the CDC's estimates of nursing home vaccination rates which have remained between 71% and 78% since the 2005-06 influenza season (CDC, 2020b). 1% and 23% experienced an influenza and influenza-like-illness, respectively. 2% had an influenza-related death.

Table 4 shows summary statistics, averaged across residents in states that implemented a resident vaccination requirement before 2011, between 2011 and 2014, and after 2014 or never. Across all groups, the majority of nursing home residents are female, the average age is about 81, and the majority of residents have at least one underlying chronic condition.

[24] A 30-day window was chosen for consistency with studies of influenza-related deaths among Medicare beneficiaries, see Shay et al. (2017) and Bolge et al. (2020).

[25] The ICD-10 code used to classify influenza are 487-488. The ICD-10 codes used to document influenza/pneumonia are 480-488. There are multiple reasons why influenza is infrequently documented on death certificates. First, states are not required to report influenza illnesses or deaths among people age 18 and older. Second, people often die of influenza-related complications rather than influenza alone, and influenza is rarely documented on death certificates in these instances. Third, many people who die of influenza are not tested for influenza or delay seeking medical care and influenza tests are most accurate within a week of the onset of illness (CDC, 2018b).

[26] The ICD-10 codes that classify respiratory and circulatory diagnoses are 390-519.

4 Empirical Strategy

4.1 Difference-in-differences specification

Three states (Arizona, Georgia, and Nebraska) adopted regulations regarding resident vaccination requirements and three states (Colorado, Georgia, and Oregon) adopted healthcare worker vaccination requirements during the study period (2011 and 2014).[27] Figures 1 and 2 show which states implemented requirements prior to 2011, between 2011 and 2014, and after 2014 or never, for residents and healthcare workers, respectively.

I exploit the quasi-experimental variation in the staggered implementation of the vaccination requirements across states and over time to estimate the impact of the requirements using difference-in-differences (DD) methods. I estimate both linear probability and logistic models to compare changes in vaccination take-up and health outcomes of nursing home residents in states that implemented a vaccination requirement to contemporaneous changes of residents in states that did not.[28] The general estimating equation is:

$$y_{ist} = \beta_0 + \beta_1 Treat_s \times Post_t + \gamma X_{ist} + \eta X_{st} + \delta_s + \delta_t + \epsilon_{ist} \quad (1)$$

where resident, state, and time are indexed by i, s, and t, respectively. The outcome variable, y, is a binary variable equal to 1 if the resident received vaccination in the calendar-quarter or in an earlier calendar-quarter within the flu season. When the outcomes are influenza-related illness and mortality, the outcome variable is equal to 1 if the resident experienced the influenza-related health outcome in the specific calendar-quarter. $Treat_s$ is a binary variable set to 1 for states that implemented vaccination requirements between 2011 and 2014.[29] $Post_t$ is an indicator equal to 1 if the individual's outcome occurred after policy implementation and the policy was implemented in the first quarter of the influenza season. If the policy was implemented in the second half of the influenza season, $Post_t$ is equal to 1 beginning the first quarter of the following influenza season. X_{it} is a vector of individual characteristics, such as demographics (age, gender),

[27] Arizona and Georgia implemented *regulations* pertaining to resident vaccination requirements in 2013. Both states, however, had *laws* pertaining to resident vaccination requirements prior to 2011. In my main analyses, I use the 2013 implementation dates for Arizona and Georgia, but I also estimate additional specifications that consider implementation prior to 2011.

[28] Logit models are estimated in addition to linear probability models because the latter may not be appropriate in the case of binary outcomes. Linear models with binary outcomes may produce predicted probabilities outside the 0-1 range and estimates could be biased.

[29] I estimate separate regressions for each policy of interest (resident and healthcare worker requirements). When the outcome is influenza-related diagnoses or deaths, some models include both $Treat$ variables for the two types of requirements.

conditions suggesting weakened immune systems (anemia, HIV, AIDS, liver disorders, and heart disease), and chronic conditions known to be risk factors for influenza (asthma, diabetes, and kidney disease). X_{st} is a vector of time-varying state characteristics, such as median income and the number of nursing home residents in the state. δ_s is a vector of general state effects, which captures any between-state differences in the outcomes that did not change over time. δ_t is a vector of general time effects, which captures any national secular trend in influenza-related adverse events over time. The set of time fixed effects will also capture the effects of national policies or trends in influenza outbreaks that apply to all states.

I also extend Equation (1) in an alternative specification, where I consider cross-facility variation in resident influenza vaccination rates and employ a dose-response DD estimation strategy. This strategy compares changes in outcomes in nursing homes where the requirements had the potential to effect a larger percentage of residents to outcomes in nursing homes where the requirements have would have limited impact (because the nursing home already had high vaccination rate). Vaccination requirements should have larger effects in facilities with low vaccination rates, because a greater fraction of residents are exposed to the requirement.

4.2 Identification

This assumption of the DD method for β_1 to identify causal effects of vaccination requirements relies on the common shock assumption, where any shock occurring during or after the implementation of vaccination requirements should equally affect nursing home residents in both states that implemented the requirement and those that did not. Additionally, the DD method assumes that outcomes of residents in both states that implemented vaccination requirement and those that did not would have similar outcome trends absent the implementation of vaccination requirement (parallel trends assumption) (Angrist and Pischke, 2008). Systematic differences in outcomes between treatment and control states prior to mandate implementation since such differences might be indicative of policy endogeneity. Although this assumption is fundamentally untestable, I examine whether there were similar trends of outcomes prior to requirement implementation. Such parallel trends are tested using the event study specified by the following equation:

$$y_{st} = \beta_0 + \sum_{d=-6, d\neq -1}^{d=4} \mathbb{1}\gamma_d(t - e^s = d) + \delta_s + \delta_t + \epsilon_{st} \tag{2}$$

where d is the season relative to requirement implementation, t is time (influenza season), and

e^s is the time of mandate implementation for state s. Due to the limited number of years for which I have MDS and Medicare data, I use Nursing Home Compare data from 2006-2017 to estimate these event studies at the state-influenza season level.[30] The identification in Equation (2) uses states that have not yet experienced the event to control for underlying trends. In the event study, the first post-implementation period is specified as zero and the season before requirement implementation is the reference period. The relative time dummy variables are equal to zero for all states that never implement a vaccination requirement for the entire study period. The variation in the timing of vaccination requirement implementation identifies the coefficient estimates of γ_d. Additionally, the event study specification allows me to observe whether any observed policy effects remain constant, increase, or decrease over time.

4.3 Inference

DD models typically cluster standard errors at the treatment group level (i.e. state-level for a model that exploits state-level policy variation). Robust standard errors are clustered at the state level (and facility level in robustness checks). This clustering is necessary because the default assumption of independent error terms is likely to underestimate standard errors (Cameron and Miller, 2015).

However, this approach can generate underestimates of the standard errors when the number of treated groups is small. Ferman and Pinto (2019) suggest that inference should account for imbalances in the number of observations in treatment and control groups. To address concerns about relying on residents in few states as the experimental units, I test the sensitivity of my results to inferential methods proposed by Donald and Lang (2007). In the first step, I estimate the regression-adjusted differences in outcomes between treatment and comparison group residents for each time period. The estimating equation of the first-stage regression is:

$$y_{it} = \pi_t Treat_i + \gamma X_{it} + \eta X_{st} + \delta_s + \delta_t + \epsilon_{it} \quad (3)$$

for each individual i with an assessment at year-quarter t. The vector π captures regression-adjusted differences between the treatment and comparison group residents in each time period. In the second step, I collapse the adjusted data into 16 year-quarter cells and estimate bivariate regressions of the adjusted treatment-comparison group differences on the $Post$ indicator:

[30] I have four years of MDS and Medicare claims data (2011-14) and cannot estimate an event study at the resident-quarter level given the limitations of pre- and post- data.

$$\hat{\pi}_t = \rho_0 + \rho_1 Post_t + u_t \tag{4}$$

where ρ_1 represents the DD effect of the vaccination requirement on the outcome of interest. A non-zero estimate implies that the difference in outcomes between the treatment and comparison group residents changed after the implementation of a vaccination requirement.

5 Results

5.1 Vaccinations

Table 5 shows the main results for the effects of resident influenza vaccination requirements on influenza vaccination (first stage). Each column represents one DD model as specified in Equation (1) and estimated at the resident-quarter level. I add control variables stepwise from left to right, starting with the most parsimonious model on the left, to the most saturated model which includes both individual and state control variables. The robustness of the main coefficient estimates to the addition of control variables suggest that it is less likely that they are correlated with unobservables that affect the outcome variable. Because the estimated marginal effects obtained from linear probability and logit models are similar, I discuss the results from linear probability models for ease of interpretation.

Columns 1-3 reveal statistically significant coefficient estimates of 4.1-4.7 percentage points. Although the effect sizes vary slightly, the estimates are not significantly different across the three models. The preferred specification in column (3) suggests that the predicted probability that a resident received an influenza vaccination increased by 4.6 percentage points following the implementation of the resident vaccination requirement. For reference, 73% of residents in states that implemented a resident vaccination requirement between 2011 and 2014 had received an influenza vaccination prior to requirement implementation. This implies that following the implementation of the resident vaccination requirements, there was a 6% increase in the probability that a resident received an influenza vaccination.

The increase in the probability of influenza vaccination among nursing home residents is fairly small. One possible explanation for the small increase is that the states that implemented a vaccination requirement were already approaching a ceiling for vaccinations. Theoretically, the vaccination rate is unlikely to reach 100 percent because some people have health conditions that preclude them from being vaccinated and some states also allow philosophical exemptions. While vaccination requirements could increase the probability of vaccination among those who previously would have sought a philosophical exemption, it is not clear what the maximum vaccination rate could be (i.e. 100 minus the percentage of residents with medical contraindications). Another explanation for the small increase is that the requirements were weakly enforced and consequently had limited impact on the vaccination practices of nursing homes.[31] Despite the small effect size, any increase in the number of vaccinated residents increases the number of people who are potentially resistant or have some level of immunity, which can reduce the spread of a virus among both vaccinated and vaccinated residents as well as people they are in contact with.

Figure 3 and Figure 4 show the estimates produced by Equation (2) for long- and short-stay residents, respectively. These events studies, which are estimated at the state-flu season level using data from Nursing Home Compare, produce estimates in both the pre- and post-period are not statistically different from zero. While this suggests that the parallel trends assumption is valid, the noisy post-period estimates differ from the statistically significant and positively signed estimates produced at the resident-quarter level using MDS and Medicare claims data (in Table 5). However, the wide confidence intervals in the event studies appear to contain the effects estimated at the individual-level.

5.2 Illnesses

The reduced-form estimates of vaccination requirements on influenza-like illness (ILI) are presented in Table 6.[32] Panel A reports the effects for a linear probability model and Panel B reports the marginal effects for a logit model. Columns 1-3 present estimates where the policy of interest is resident vaccination requirement, columns 4-6 present estimates where the policy of interest is healthcare worker vaccination requirement, and columns 7-9 report the estimates when both resident and healthcare worker vaccination requirements are estimated in the same model. Unlike vaccination where I do not expect healthcare worker vaccination requirements to impact resident vaccination, healthcare worker vaccination could potentially affect resident health outcomes; a

[31]However, failure to comply with regulations and meet minimum standards can have have negative consequences for nursing homes. For example, nursing homes can be cited by the state's Department of Public Health which can put holds on admissions of new patients. Additionally, deficiencies could be brought to the attention of a payer or CMS. These entities can stop payments which can be disastrous for nursing homes since many already operate on very slim margins. However, failure to comply with one regulation related to influenza vaccination requirements alone may be insufficient to trigger these negative consequences.

[32]As seen in Table 3, influenza diagnoses are very rare relative to the broader diagnosis of ILI. These results are presented in Table A4.

vaccinated healthcare worker is less likely to contract influenza either in or outside of the nursing home and would therefore be less likely to transmit the virus to a resident.

In Table 6, columns 1-3 show that resident vaccination requirements reduce the predicted probability of ILI by roughly 4.4 percentage points (20%) and the estimates are similar for both linear probability and logit models. Columns 5-6 show that healthcare worker vaccination requirements reduce the predicted probability that a resident experienced an ILI by 3.9 to 4.1 percentage points, offering some evidence of external benefits of healthcare worker vaccination to residents. This effect could operate through several channels. First, because the effectiveness of influenza vaccination depends on the vaccinated person's immune system response, vaccines tend to be more effective for healthcare workers, who are younger and healthier, relative to nursing home residents who are older and in worse health. Second, healthcare workers may interact with many residents while residents may interact with fewer other residents. If this is the case, the number of potential residents that a healthcare worker could infect is greater than the number of potential residents that another resident could infect. Third, a fraction of healthcare workers work across multiple facilities, which can potentially facilitate the spread of infections. The effect sizes for both resident and healthcare worker vaccination requirements decrease when both treatment indicators are included (columns 7-9), and the estimates of healthcare worker requirements are no longer significant when both policies are included in the same regression. Because the two treatment variables are highly correlated, I cannot independently estimate the effects of these requirements on influenza-related deaths. However, the results suggest that each policy may individual reduce ILI by a statistically significant and economically important amount.

5.3 Deaths

The reduced-form estimates of vaccination requirements on influenza-related deaths are presented in Table 7. Panel A reports the effects for a linear probability model and Panel B reports the effects for a logit model. Columns 1-3 present estimates where the policy of interest is resident vaccination requirement, columns 4-6 present estimates where the policy of interest is healthcare worker vaccination requirement, and columns 7-9 report the estimates when both resident and healthcare worker vaccination requirements are estimated in the same model. Resident and healthcare worker vaccination requirements individually reduce influenza-related deaths by 0.15 to 0.20 percentage points (9-13%). However, columns 7-9 show that when both resident and healthcare worker requirements are included in the same regression, only resident requirements are statistically significant. Because the two treatment variables are highly correlated, I cannot independently estimate the effects of these requirements on influenza-related deaths.

[Results from state-level analyses using NVSS data will be added.]

5.4 Heterogeneity

Next, I examine the effects of the vaccination requirements for several subgroups of interest. First I consider whether the requirements have different effects on residents with different stay lengths (long stays of $>$ 100 days and short-stays of $\leq$ 100 days). A priori, it is unclear which type of patient is at greater risk of adverse health outcomes. On the one hand, long-stay residents typically have multiple comorbidities and have chronically poorer health. On the other hand, short-stay residents are typically in the nursing home for post-acute care and are temporarily but acutely ill. Table 8 shows the effects of the requirements on vaccinations, diagnoses, and deaths by resident's length of stay. Resident vaccination requirements increase vaccination take-up by about 1.1 percentage points among long-stay residents and 2.4 percentage points among short-stay residents. However, the effects on ILI diagnoses are greater for long-stay residents than for short-stay residents.

Second, I estimate the effects of the policy by age group. Older individuals are at higher risk of influenza and influenza-related mortality because the immune system weakens with age, so I expect larger reductions in adverse health outcomes among the oldest residents. However, older people can also be less responsive to the vaccine relative to other age groups so vaccinating other residents and staff in the nursing home is one strategy to protect a very vulnerable population from influenza. Although the effect sizes vary slightly, the estimates on vaccination and ILI diagnoses are not significantly different across age groups. The estimates of the requirements on influenza-related deaths are also similar across age group, but only statistically significant for the oldest age group (85+ years).

Third, Table 10 shows the effects separately for peak (October-December and January-March) and non-peak quarters (April-June and July-September). Ex-ante, the size of the effects are ambiguous. On the one hand, effect sizes might be larger during peak quarters because vaccinations are typically administered beginning in October and influenza-related diagnoses and deaths typically occur during winter months. On the other hand, vaccinations during non-peak quarters may increase for residents arriving in the spring or summer if nursing homes are concerned with compliance. In this case, vaccination requirements for residents, particularly short-stay residents, would be inframarginal for people during the typical flu season since they would have received the vaccine regardless of the requirement. In the off-season, however, requirements may push more residents to get vaccinated.

5.5 Robustness

I re-estimate Equation (1) with the standard errors clustered at the facility-level. Although the vaccination policies were implemented at the state-level, in practice, it is likely that facilities vary in their adherence to federal and state regulations. Additionally, I estimate models that include facility fixed effects to control for unobserved factors across facilities. [This will be included in future draft.]

Next, because few states implemented policies between 2011 and 2014, the numbers of observations in treated and control groups are not balanced. Consequently, I implement the two-step method proposed by Donald and Lang (2007) to adjust for having few treated units. Though slightly smaller, the coefficient and standard errors obtained using this two-step method are similar to those reported in Tables 5, 6, and 7.

Additionally, I conduct falsification checks that test for spurious patterns in the data structure. I exclude treated states and assign a randomized pseudo treatment status to remaining states that did not have vaccination requirements. [This will be included in future draft.]

DD analyses rely on the assumption that the outcomes in treatment and control groups would have followed parallel trends in the absence of policy implementation. Synthetic controls are an alternative method for causal inference with few treated units and many control units. As a robustness exercise, I implement the synthetic control approach proposed by Abadie et al. (2010) in analyses at the state-level. This method selects control states that exhibit similar pre-treatment characteristics and dynamics as those in the treatment states and calculates treatment effects by comparing treatment states to their synthetic counterpart. By selecting a weighted subset of states as the control group, this method identifies states that are a more ideal control group for each state that experienced treatment. To implement this synthetic control method, I generate state outcomes, and states are then weighted using the pre-policy trend in outcomes. The final vector of state weights sum to one, such that each synthetic treated state is the weighted average of the selected control states. I then compare outcomes in each treated state and synthetic treated state graphically, where the treatment effect is represented by the difference in outcomes between the two groups over time. [This will be included in future draft.]

6 Discussion

The goal of this research is to better understand how vaccination requirements can reduce the spread of infectious diseases and improve public health. In this paper, I estimate the effects of resident and healthcare worker influenza vaccination requirements on influenza vaccination, and influenza-related illnesses and deaths among nursing home residents. I find that resident vaccination requirements increase the predicted probability of vaccination by about 6%. This increase in influenza vaccination decreases ILI diagnoses by about 20%. These results apply to nursing home residents with Medicare fee-for-service and dual enrollment in both Medicare and Medicaid. A back-of-the-envelope calculation suggests that the resident vaccination requirements implemented by three states translates to 226 fewer influenza-related hospitalizations, though this is likely a much lower bound estimate of the true reduction in influenza-related hospitalizations.[33]

There are several limitations of this paper. First, while this paper is interested in the effects of both resident and healthcare worker vaccination requirements, I do not have data on healthcare worker vaccination and consequently cannot observe whether vaccination take up increases following the implementation of healthcare worker vaccination requirements. Second, there are several scenarios that may suggest that my estimates have upward or downward bias. My results will overstate the effects of the vaccination requirements, if individual facilities in states with state-wide requirements have stricter policies beyond those of state regulations. Additionally, facilities in states that implemented requirements could also have had their own vaccination policies prior to the laws and regulations. Alternatively, states without state-wide vaccination requirements may have facilities that implement their own vaccination policies. If these policies appeared more often in states without state laws or regulations, my results will understate the effects of these requirements. However, if nursing homes were more likely to require residents and workers to be vaccinated after states passed laws or regulations, then spurring change in nursing homes poli-

[33]For the 2018-19 flu season, there were an estimated 279,384 influenza-related hospitalizations among people 65 years and older (CDC, 2020c). Adults living in nursing homes account for 4.5% of all adults 65 and older in the U.S, suggesting that 12,572 hospitalizations occurred among people 65 and older and in nursing homes (279,384 $\times$ 0.045). However, this is likely a lower bound estimate since older adults in nursing homes are more frail than community dwelling older people so older adults from nursing homes likely account for more than 4.5% of hospitalizations among the 65+ population. If resident vaccination requirements decrease the predicted probability of ILI diagnosis by about 20% and and an estimated 9% of symptomatic influenza illnesses result in hospitalization among the 65+ population (279,384 hospitalizations / 3,073,337 symptomatic influenza illnesses), then the percent change in influenza-related hospitalization as a result of the resident requirements is about 1.8% (0.20 $\times$ 0.09). Again, however, because the 65+ nursing home population is more frail than the community dwelling 65+ population, the percentage of influenza illness that require hospitalization among nursing home residents likely exceeds 9%. The resulting lower bound estimate of the reduction in the number of hospitalizations is 226 (12,572 $\times$ 0.018).

cies may be an important pathway through which the laws and regulations increase vaccination take-up and reduce ILI diagnoses.

Additionally, I find some evidence of an external benefit of healthcare worker vaccinations; the probability of an ILI diagnoses decreases by about 12% following the implementation of a healthcare worker vaccination requirement. However, I do not have data on healthcare worker vaccination and consequently cannot observe whether vaccination take-up increases following the implementation of healthcare worker vaccination requirements.

Nursing home residents are a particularly vulnerable population, which has been highlighted by the COVID-19 pandemic. Although only 0.6% of the population resides in long-term care facilities which include nursing homes, an estimated 45% of COVID-19 deaths have occurred in these facilities (Kaiser Family Foundation, 2020). The current pandemic has highlighted concern about the spread of communicable diseases within nursing homes and the importance of infection control policies in these settings. Effective policies to reduce the spread of infectious disease among nursing homes not only benefits the nursing home residents but also generates social benefits. Additionally, infection reductions for illnesses such as influenza in nursing homes and other long-term care facilities can relieve hospital systems which have been overburdened this past year with COVID-19 cases. Although a COVID-19 vaccine does not yet exist, this paper may help to inform future policies that consider COVID-19 vaccination requirements, particularly for older adults and healthcare workers in nursing homes.

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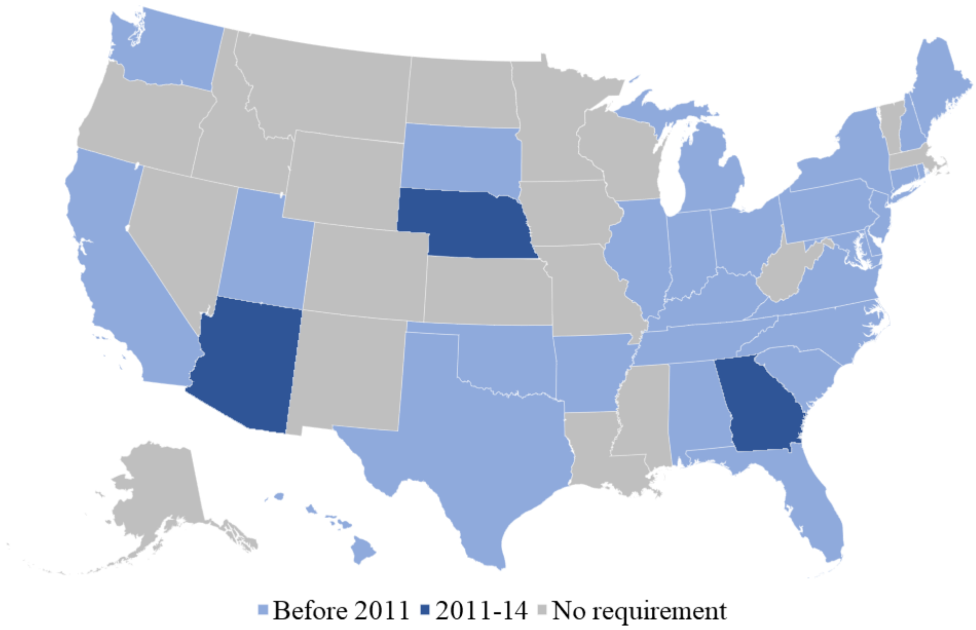


Figure 1: Implementation years of influenza vaccination requirements for residents

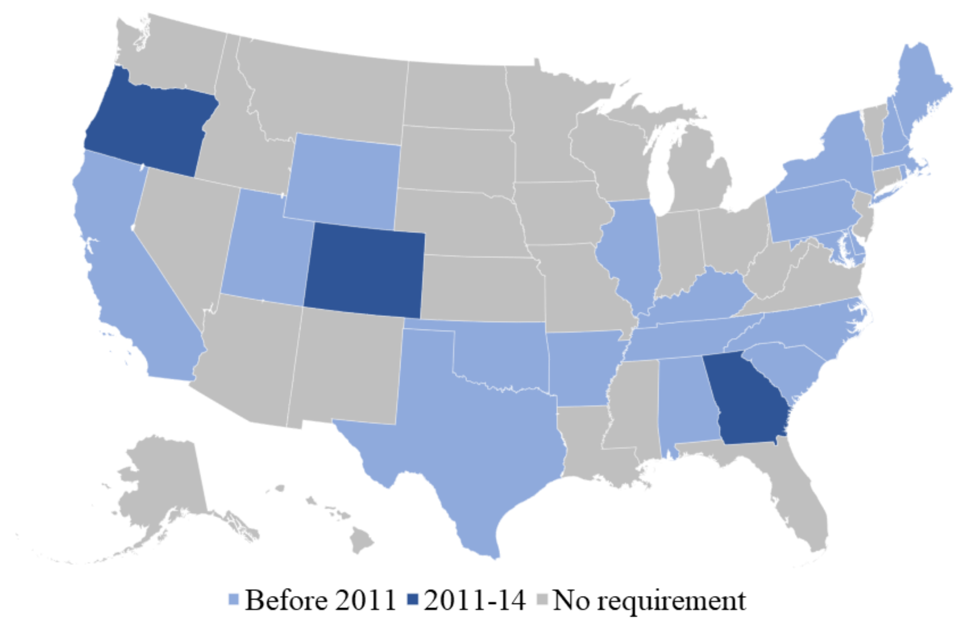


Figure 2: Implementation years of influenza vaccination requirements for healthcare workers

Figure 3: First stage event study, long-stay resident vaccination rate

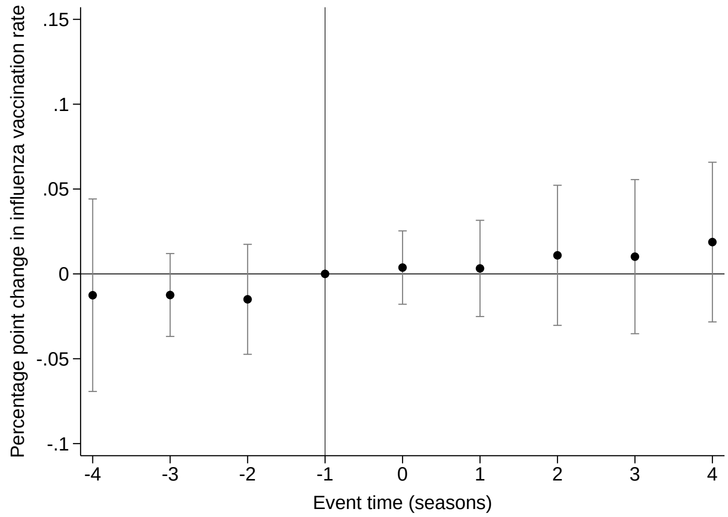
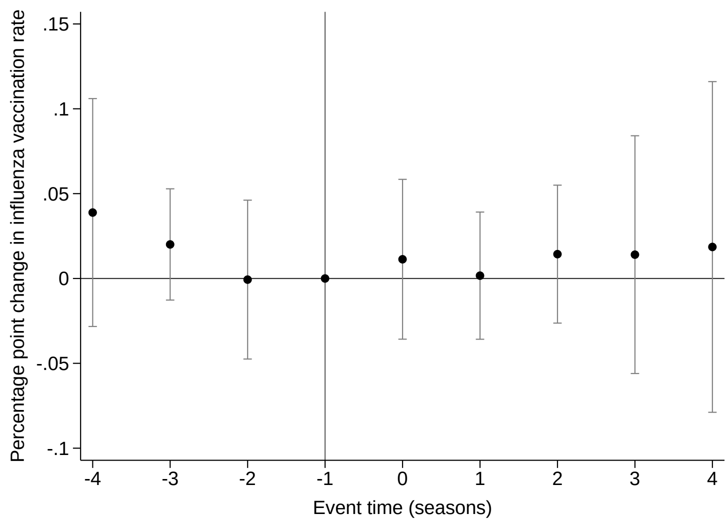


Figure 4: First stage event study, short-stay resident vaccination rates



Notes: These figures plots the event study specified by Equation (2). The unit of observation is state-flu season. The x-axis illustrates the normalized time before and after requirements became effective and the vertical line indicates the flu season prior to the effective date. The y-axis indicates the change in influenza vaccination rates. Estimates are calculated using data from Nursing Home Compare.

Table 1: Resident influenza vaccination requirements

State	Year Effective	Requirement Type: Assessment	Offer	Ensure	Exemptions: Medical	Religious	Philosophical
Alabama	2001			X	X	X	X
Alaska							
Arizona	2000/2013		X		X		X
Arkansas	2005			X	X	X	X
California	2005		X		X		X
Colorado							
Connecticut	2002			X	X	X	
Delaware	2005			X	X		X
District of Columbia	2002			X	X	X	X
Florida	2001			X	X	X	X
Georgia	2004/2013		X		X		
Hawaii	2011			X	X		X
Idaho							
Illinois	2003			X	X		X
Indiana	1999			X	X	X	X
Iowa							
Kansas							
Kentucky	2002			X	X	X	X
Louisiana							
Maine	2002		X		X		X
Maryland	2000			X	X	X	X
Massachusetts							
Michigan	2001		X				
Minnesota							
Mississippi							
Missouri							
Montana							
Nebraska	2012		X		X		
Nevada							
New Hampshire	2005			X	X	X	
New Jersey	2002			X	X		X
New Mexico							
New York	2000			X	X	X	X
North Carolina	2000			X	X	X	X
North Dakota							
Ohio	2006		X		X		X
Oklahoma	1999		X		X		X
Oregon							
Pennsylvania	2002			X	X	X	X
Rhode Island	2000			X	X	X	X
South Carolina	2008			X	X		X
South Dakota	1987			X	X	X	X
Tennessee	2003			X	X		X
Texas	1999			X	X		X
Utah	2002		X		X		X
Vermont							
Virginia	2004			X	X		X
Washington	2002		X				
West Virginia							
Wisconsin							
Wyoming							

Notes: Author's determination based on searches of legal databases such as Nexis Uni and HeinOnline, as well as independent research.

Table 2: Healthcare worker influenza vaccination requirements

		Requirement Type			Exemptions			
State	Year Effective	Assessment	Offer	Ensure	Surgical Mask	Medical	Religious	Philosophical
Alabama	2001			X		X	X	X
Alaska								
Arizona								
Arkansas	1999			X		X	X	
California	2010		X			X		X
Colorado	2012			X	X	X		
Connecticut								
Delaware	2018	X		X				X
District of Columbia	2002			X		X	X	X
Florida								
Georgia	2013		X					X
Hawaii								
Idaho								
Illinois	2010		X			X	X	x
Indiana								
Iowa								
Kansas								
Kentucky	2002			X		X	X	X
Louisiana								
Maine	2002			X		X	X	X
Maryland	2000			X		X	X	X
Massachusetts	2007			X		X	X	X
Michigan								
Minnesota								
Mississippi								
Missouri	2016		X			X		X
Montana								
Nebraska	2017							
Nevada								
New Hampshire	2005			X		X	X	
New Jersey								
New Mexico								
New York	2000			X		X	X	X
North Carolina	2000			X		X	X	X
North Dakota								
Ohio								
Oklahoma	1999/2001		X			X		X
Oregon	2014	X				X		X
Pennsylvania	2002			X		X	X	X
Rhode Island	2000			X		X	X	X
South Carolina	2008			X		X		X
South Dakota								
Tennessee	2007			X		X		X
Texas	2000			X		X		X
Utah	2002		X			X		X
Vermont								
Virginia								
Washington								
West Virginia								
Wisconsin								
Wyoming								

Notes: Author's determination based on searches of legal databases such as Nexis Uni and HeinOnline, as well as independent research.

Table 3: Summary statistics for all residents

	Mean	Std Dev
Covariates		
Female	0.68	0.47
Age	80.90	11.46
Anemia	0.32	0.47
Asthma	0.23	0.42
Coronary artery disease	0.25	0.43
Diabetes mellitus	0.33	0.47
Heart failure	0.23	0.42
Any chronic condition	0.69	0.46
State median income ($)	57,744	9,309
Number of nursing home residents	26,694	26,875
Outcomes		
Influenza vaccination	0.72	0.45
Influenza diagnosis	0.01	0.07
Influenza-like illness diagnosis	0.24	0.43
Influenza-related death	0.02	0.14

Notes: Data is from the Long-Term Care Minimum Data Set, Medicare claims, Census Bureau, and U.S. Bureau of Labor Statistics

Table 4: Summary statistics for residents by treated status

	2011-14		Pre-2011		Post-2014 or never	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Covariates						
Female	0.67	0.47	0.68	0.47	0.67	0.47
Age	80.84	11.43	80.50	11.31	81.18	11.58
Anemia	0.33	0.47	0.30	0.46	0.29	0.46
Asthma	0.23	0.42	0.23	0.42	0.23	0.42
Coronary artery disease	0.25	0.43	0.23	0.42	0.22	0.42
Diabetes mellitus	0.33	0.47	0.33	0.47	0.31	0.46
Heart failure	0.23	0.42	0.22	0.41	0.23	0.42
Any chronic condition	0.70	0.46	0.68	0.47	0.67	0.469
State median income ($)	58,467	9,591	55,382	4,135	57,014	9,366
Number of nursing home residents	35,434	31,381	17,361	8,290	14,830	12,465
Outcomes	0.00	0.00	0.00	0.00	0.00	0.00
Influenza vaccination	0.70	0.46	0.73	0.45	0.76	0.43
Influenza diagnosis	0.01	0.08	0.00	0.07	0.00	0.07
Influenza-like illness diagnosis	0.53	0.43	0.22	0.41	0.21	0.41
Influenza-related death	0.02	0.14	0.02	0.13	0.02	0.13

Notes: Data is from the Long-Term Care Minimum Data Set, Medicare claims, Census Bureau, and U.S. Bureau of Labor Statistics

Table 5: Effects of requirements on influenza vaccination among residents

	(1)	(2)	(3)
Panel A. OLS			
Resident requirement	0.0467***	0.0416***	0.0459***
	(0.0043)	(0.007)	(0.0075)
Panel B. Logit			
Resident requirement	0.0474***	0.0468***	0.0462***
	(0.0045)	(0.0045)	(0.0086)
Mean	0.7258	0.7258	0.7258
Observations	13,825,743	13,823,477	13,823,477
State FE	X	X	X
Time FE	X	X	X
Individual controls		X	X
State controls			X

Notes: This table reports the impact of influenza vaccination requirements on influenza vaccination take-up among residents (marginal effects reported in Panel B). This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *$p<0.1$,**$p<0.05$,***$p<0.01$.

Table 6: Effects of requirements on influenza-like illness diagnoses among residents

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS									
Resident requirement	-0.0448***	-0.0441***	-0.0439***				-0.0340**	-0.0337**	-0.0351**
	(0.0057)	(0.0052)	(0.0074)				(0.0140)	(0.0131)	(0.0155)
Healthcare worker requirement				-0.0418***	-0.0410***	-0.0387***	-0.0201	-0.0195	-0.0162
				(0.0037)	(0.0029)	(0.0056)	(0.0181)	(0.0169)	(0.0208)
Panel B. Logit									
Resident requirement	-0.0461***	-0.0451***	-0.0445***				-0.0352**	-0.0345**	-0.0359**
	(0.0063)	(0.0056)	(0.0086)				(0.0151)	(0.0140)	(0.0172)
Healthcare worker requirement				-0.0414***	-0.0405***	-0.0378***	-0.0196	-0.0191	-0.0155
							(0.0187)	(0.0174)	(0.0220)
Observations	14,183,622	13,905,698	13,905,698	14,183,622	13,905,698	13,905,69	14,183,622	13,905,698	13,905,69
State FE	X	X	X	X	X	X	X	X	X
Time FE	X	X	X	X	X	X	X	X	X
Individual controls		X	X		X	X		X	X
State controls			X			X			X

Notes: This table reports the impact of influenza vaccination requirements for nursing home residents and healthcare workers on influenza-like illness diagnoses among residents (marginal effects reported in Panel B). This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents (or healthcare workers) in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *p<0.1,**p<0.05,***p<0.01.

Table 7: Effects of requirements on influenza-related deaths

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS									
Resident requirement	-0.0017***	-0.0020***	-0.0020***				-0.0014*	-0.0015*	-0.0016
	(0.0005)	(0.0005)	(0.0006)				(0.0008)	(0.0009)	(0.0010)
Healthcare worker requirement				-0.0015***	-0.0018***	-0.0017***	-0.0005	-0.0008	-0.0007
				(0.0005)	(0.0005)	(0.0005)	(0.0011)	(0.0011)	(0.0013)
Panel B. Logit									
Resident requirement	-0.0019***	-0.0021***	-0.0021***				-0.0016*	-0.0016*	-0.0017*
	(0.0006)	(0.0005)	(0.0006)				(0.0009)	(0.0009)	(0.0010)
Healthcare worker requirement				-0.0015***	-0.0019***	-0.0018***	-0.0006	-0.0009	-0.0008
				(0.0005)	(0.0005)	(0.0006)	(0.0011)	(0.0011)	(0.0013)
Observations	14,183,622	13,905,698	13,905,698	14,183,622	13,905,698	13,905,69	14,183,622	13,905,698	13,905,69
State FE	X	X	X	X	X	X	X	X	X
Time FE	X	X	X	X	X	X	X	X	X
Individual controls		X	X		X	X		X	X
State controls			X			X			X

Notes: This table reports the impact of influenza vaccination requirements for nursing home residents and healthcare workers on influenza-related deaths among residents (marginal effects reported in Panel B). This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents (or healthcare workers) in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *p<0.1,**p<0.05,***p<0.01.

Table 8: Effects of requirements on outcomes by resident length of stay

	Long-stay			Short-stay		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Vaccinations						
Resident requirement	0.0106***			0.0236***		
	(0.0025)			(0.0068)		
Panel B. Diagnoses						
Resident requirement	-0.0158***		-0.0106	-0.0066***		-0.0066***
	(0.0036)		(0.0090)	(0.0021)		(0.0022)
Healthcare worker requirement		-0.0161***	-0.0089		-0.0037*	-0.0000
		(0.0054)	(0.0118)		(0.0019)	(0.0018)
Panel C. Deaths						
Resident requirement	0.0004		0.0002	0.0030***		0.0025**
	(0.0003)		(0.0005)	(0.0008)		(0.0012)
Healthcare worker requirement		0.0004	0.0003		0.0024***	0.0010
		(0.0003)	(0.0004)		(0.0006)	(0.0012)
Observations	8,907,829	8,907,829	8,907,829	4,997,869	4,997,869	4,997,869
State FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Individual controls	X	X	X	X	X	X
State controls	X	X	X	X	X	X

Notes: This table reports the impact of influenza vaccination requirements on influenza-related outcomes among residents. This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *p<0.1,**p<0.05,***p<0.01.

Table 9: Effects of requirements on outcomes by resident age

	Under 65			65-74		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Vaccinations						
Resident requirement	0.0383***			0.0468***		
	(0.0102)			(0.0089)		
Panel B. Diagnoses						
Resident requirement	-0.0454***		-0.0341*	-0.0414***		-0.0315*
	(0.0084)		(0.0183)	(0.0080)		(0.0172)
Healthcare worker requirement		-0.0497***	-0.0180		-0.0379***	-0.0169
		(0.0038)	(0.0204)		(0.0041)	(0.0192)
Panel C. Deaths						
Resident requirement	-0.0010		-0.0017	-0.0007		-0.0008
	(0.0008)		(0.0010)	(0.0007)		(0.0009)
Healthcare worker requirement		-0.0001	0.0010		-0.0005	0.0000
		(0.0004)	(0.0012)		(0.0006)	(0.0010)
Observations	1,247,433	1,247,433	1,247,433	2,159,999	2,159,999	2,159,999

	75-84			85+		
	(7)	(8)	(9)	(10)	(11)	(12)
Panel A. Vaccinations						
Resident requirement	0.0483***			0.0434***		
	(0.0058)			(0.0079)		
Panel B. Diagnoses						
Resident requirement	-0.0375***		-0.0287*	-0.0468***		-0.0391**
	(0.0063)		(0.0145)	(0.0082)		(0.0152)
Healthcare worker requirement		-0.0350***	-0.0164		-0.0394***	-0.0154
		(0.0069)	(0.0199)		(0.0058)	(0.0217)
Panel C. Deaths						
Resident requirement	-0.0004		-0.0003	-0.0037***		-0.0027***
	(0.0008)		(0.0011)	(0.0003)		(0.0008)
Healthcare worker requirement		-0.0004	-0.0002		-0.0035***	-0.0019*
		(0.0010)	(0.0014)		(0.0002)	(0.0011)
Observations	4,319,452	4,319,452	4,319,452	6,178,814	6,178,814	6,178,814
State FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Individual controls	X	X	X	X	X	X
State controls	X	X	X	X	X	X

Notes: This table reports the impact of influenza vaccination requirements for nursing home residents and healthcare workers on influenza-like illness diagnoses among residents. This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents (or healthcare workers) in nursing homes has been implemented. The unit of observation is resident-quarter. Peak quarters are defined calendar quarters 1 (January to March) and 4 (October to December), and non-peak quarters are defined as quarters 2 (March to June) and 3 (July to September). Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *p<0.1,**p<0.05,***p<0.01.

Table 10: Effects of requirements on outcomes by peak and non-peak quarters

	Peak			Non-peak		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Vaccinations						
Resident requirement	-0.0052			0.0746***		
	(0.0036)			(0.0216)		
Panel B. Diagnoses						
Resident requirement	-0.0400***		-0.0293*	-0.0498***		-0.0411***
	(0.0086)		(0.0172)	(0.0070)		(0.0153)
Healthcare worker requirement		-0.0381***	-0.0190		-0.0427***	-0.0170
		(0.0072)	(0.0202)		(0.0044)	(0.0220)
Panel C. Deaths						
Resident requirement	-0.0017***		-0.0013	-0.0027***		-0.0020*
	(0.0006)		(0.0010)	(0.0006)		(0.0012)
Healthcare worker requirement		-0.0016***	-0.0007		-0.0026***	-0.0013
		(0.0066)	(0.0011)		(0.0007)	(0.0016)
Observations	6,973,073	6,973,073	6,973,073	6,932,625	6,932,625	6,932,625
State FE	X	X	X	X	X	X
Time FE	X	X	X	X	X	X
Individual controls	X	X	X	X	X	X
State controls	X	X	X	X	X	X

Notes: This table reports the impact of influenza vaccination requirements on influenz-related outcomes among residents. This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *p<0.1,**p<0.05,***p<0.01.

Appendix A. Data and Variable Construction

Summary of data sources used

Table A1: Summary of data sources and levels of analysis

Unit of analysis	Vaccination	Illnesses	Deaths
Resident	MDS, 2011-14 Medicare claims, 2011-14	Medicare claims, 2011-14	Medicare claims, 2011-14
Facility	Nursing Home Compare, 2006-17	Medicare claims, 2011-14	Medicare claims, 2011-14
State			NVSS mortality files, 1999-2016

Details on Medicare and MDS sample

I begin with a random sample of 20 million Medicare fee-for-service beneficiaries in 2011. This represents over 50% Medicare fee-for-service beneficiaries in 2011.[34] I then identify the subset of these beneficiaries who experienced a nursing home stay between 2011 and 2014. As a result, I have both assessment and claims for roughly 3.6 million unique beneficiaries between 2011 and 2014.

[34]In 2011, there were 35.5 million beneficiaries enrolled in original fee-for-service Medicare.

Diagnosis and Procedure Codes

Table A2: ICD-9 and CPT codes for influenza vaccination

ICD-9 or CPT Code	Description
V04.81	Vaccine for influenza
90655	Influenza virus vaccine, split virus, preservative free, for children 6-35 months of age, for intramuscular use
90656	Influenza virus vaccine, split virus, preservative free, for use in individuals 3 years and above, for intramuscular use
90657	Influenza virus vaccine, split virus, for children 6-35 months of age, for intramuscular use
90658	Influenza virus vaccine, split virus, for use in individuals 3 years and above, for intramuscular use
90660	Influenza virus vaccine, live, for intranasal use
90662	Influenza virus vaccine, split virus, preservative free, enhanced immunogenicity via increased antigen content, for intramuscular use
Q2034	Influenza virus vaccine, split virus, for intramuscular use (agriflu)
Q2035	Influenza virus vaccine, split virus, when administered to individuals 3 years of age and older, for intramuscular use (afluria)
Q2036	Influenza virus vaccine, split virus, when administered to individuals 3 years of age and older, for intramuscular use (flulaval)
Q2037	Influenza virus vaccine, split virus, when administered to individuals 3 years of age and older, for intramuscular use (fluvirin)
Q2038	Influenza virus vaccine, split virus, when administered to individuals 3 years of age and older, for intramuscular use (fluzone)
Q2039	Influenza virus vaccine, not otherwise specified
G0008	Administration of influenza virus vaccine

Table A3: ICD-9 diagnosis codes for influenza and influenza-like-illness

ICD-9 Code	Description
Influenza	
487	Influenza with pneumonia
487.1	Influenza with other respiratory manifestations
487.8	Influenza with other manifestations
Influenza-like-illness	
079.89	Viral infection NEC
079.99	Viral infection NOS
460	Nasopharyngitis, acute
462	Pharyngitis, acute
464.00	Laryngitis, acute without obstruction
464.10	Tracheitis, acute without obstruction
464.20	Laryngotracheitis, acute without obstruction
465.0	Larynogopharyngitis, acute
465.8	Infectious upper respiratory, multiple sites, acute NEC
465.9	Infectious upper respiratory, multiple sites, acute NOS
466.0	Bronchitis, acute
466.11	Bronchiolitis due to respiratory syncytial virus
466.19	Bronchiolitis, acute due to other infectious organism
478.9	Disease, uper respiratory NEC/NOS
480.0	Pneumonia due to adenovirus
480.1	Pneumonia due to respiratory syncytial virus
480.2	Pneumonia due to parainfluenza
480.8	Pneumonia due to virus NEC
480.9	Viral pneumonia unspecified
484.8	Pneumonia in other infectious disease NEC
485	Brochopneumonia, organism NOS
486	Pneumonia, organism NOS
487	Influenza with pneumonia
487.1	Influenza with other respiratory manifestations NEC
487.8	Influenza with other manifestations NEC
490	Bronchitis NOS
780.6	Fever
484.1	Pain, throat
786.2	Cough

Appendix B

Table A4: Effects of requirements on influenza diagnoses among residents

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS									
Resident requirement	-0.0010***	-0.0010***	0.0010***				-0.0012***	-0.0012***	-0.0011***
	(0.0003)	(0.0003)	(0.0003)				(0.0004)	(0.0004)	(0.0004)
Healthcare worker requirement				-0.0005	-0.0005	-0.0005	0.0003	0.0003	0.0002
				(0.0005)	(0.0006)	(0.0005)	(0.0003)	(0.0004)	(0.0003)
Panel B. Logit									
Resident requirement	-0.0009**	-0.0009**	-0.0008**				-0.0013*	-0.0014*	-0.0012*
	(0.0004)	(0.0004)	(0.0004)				(0.0007)	(0.0008)	(0.0007)
Healthcare worker requirement				-0.0002	-0.0002	-0.0003	0.0006	0.0007	0.0006
				(0.0007)	(0.00008)	(0.0007)	(0.0006)	(0.0007)	(0.0006)
Observations	14,183,622	13,905,698	13,905,698	14,183,622	13,905,698	13,905,69	14,183,622	13,905,698	13,905,69
State FE	X	X	X	X	X	X	X	X	X
Time FE	X	X	X	X	X	X	X	X	X
Individual controls		X	X		X	X		X	X
State controls			X			X			X

Notes: This table reports the impact of influenza vaccination requirements for nursing home residents and healthcare workers on influenza-like illness diagnoses among residents. This table estimates equation (1) where the policy variable of interest a binary measure of whether an influenza vaccination requirement pertaining to residents (or healthcare workers) in nursing homes has been implemented. The unit of observation is resident-quarter. Estimates are calculated using data from the Long-Term Care Minimum Data Set and Medicare claims from 2011-14. Fixed effects for states and time are always included, and standard errors in parentheses are clustered at the state level. Significance levels: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.