Better to “Ensure” than “Offer”

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Abstract

While many people think “serious” when they read words like “epidemic”, “outbreak” and “communicable disease” in their newspaper, the seasonal flu is an easily neglected disease compared to other communicable diseases due to its seasonality and the popular perception that it is less serious. However, according to a Centers for Disease Control and Prevention (CDC) report, at least 10 thousand people died from flu-associated causes in 2015-2016 in the United States. Nevertheless, the overall flu vaccination rate was 45% for 2015-2016, which is far lower than the 70% CDC goal. This low vaccination rate in hospital settings is critical to patient health, as patients in a hospital are more vulnerable to flu-associated complications, which could lead to severe illness and death. Therefore, “[Eighteen] states established flu vaccination requirements for hospital healthcare workers, and 16 states establish requirements for hospital patients” (AilaHoss, DawnPepin 2015). This paper estimates the impact of the Administrative Requirements for Ensuring Vaccination to healthcare workers on flu-associated, particularly pneumonia and influenza, deaths. Results show that states with provisions ensuring healthcare workers receive influenza vaccinations have a 0.5% ~ 1% lower mortality rate from pneumonia and influenza than other states, while provisions simply offering vaccinations to healthcare workers do not have a statistically significant impact on mortality.

Keywords: influenza, mandatory flu vaccination law, hospital influenza vaccination laws, public health policy, impact evaluation

Introduction

Influenza is often neglected by the public compared to other communicable diseases due to its seasonality and the widespread perception of its low malignancy compared with other communicable diseases, such as malaria**,** tuberculosis, Ebola and Zika. However, the CDC estimates that 11 million people made visits to their doctors due to influenza and an estimated 0.3 million were hospitalized in 2015-2016 in the United States alone. Although estimated pneumonia & influenza (P&I) deaths are around 10,000, the actual total deaths associated with influenza might be 2 to 4 times higher than P&I deaths, if respiratory and circulatory (R&C) deaths, which include P&I deaths, and deaths from secondary respiratory or cardiac complications that are likely followed by influenza are also included (CDC 2016). According to a regression model by Jonathan et al. (2005), it is estimated that annual deaths from influenza over the period 1979–2001 in the United States average 41,400 per year, with a 95% confidence interval. In addition to its effect on the population, influenza induces a high socio-economic cost. According to a paper by Molinari et al. (2007), "Based on 2003 US population, direct medical costs is $10.4 billion in average, projected lost earnings due to illness and loss of life amounted to $16.3 billion annual with 95% confidence interval." Moreover, they claim that "the total economic burden of annual influenza epidemics using projected statistical life values amounted to $87.1 billion." Consequently, preventing influenza would be important for enhancing public health and economy.

There are two major methods for preventing the spread of influenza, namely non-pharmaceutical interventions (NPIs), such as development of hygienic environments and actions other than vaccinations, and pharmaceutical interventions, such as vaccinations ex-ante and antiviral drugs in ex-post. Among these preventions, vaccination has been regarded as the most common and the most effective way to prevent the flu in ex-ante period (CDC 2017). However, the United States influenza vaccination coverage has yet to reach the CDC goal of 70%, with only 45.6% of the general population vaccinated in 2015-2016 (CDC 2016). Since the benefit of the flu vaccination lies in its non-excludable and non-rivalrous status, it induces general population to be a free-rider of the benefit. Along with this overall low rate of vaccination coverage, the importance of patient and healthcare worker (HCW) vaccination has been growing, as influenza-associated deaths among low-immunity patients and aged patients are critical. The Advisory Committee on Immunization Practices' (ACIP) 2010 report also reflected, "Vaccination to prevent influenza is particularly important for persons who are at increased risk for severe complications from influenza or at higher risk for influenza-related outpatient, ED, or hospital visits." Given the recent increased attention to vaccination, several states have passed mandatory flu vaccination laws, titled Hospital Influenza Vaccination Laws, which include regulations for offering or ensuring vaccination for patients and health workers. Although detailed provisions are different among those states, we can categorize four types of detailed provisions that are in accordance with the CDC's recommendations.

- **Assessment Requirements**

Requiring a healthcare facility to assess a healthcare worker or patient's immunization status

- **Administrative Requirements for Offering Vaccination**

Requiring a healthcare facility to offer a vaccination to a healthcare worker or patient[3]

- **Administrative Requirements for Ensuring Vaccination**

Requiring a healthcare facility to ensure that a healthcare worker or patient has been vaccinated unless vaccination is specifically exempted or declined[4]

- **Surgical Mask Requirements**

Requiring a healthcare worker to wear a surgical mask during influenza (flu) season if he or she has been exempted from or declined influenza vaccinations[5]

(CDC, State Immunization Laws for Healthcare 2016)

Among these four categories, the administrative requirements are more directly related to flu vaccination, compared to the other two requirements, while the assessment requirements are focused on realizing the information and surgical mask requirements as alternatives for persons who are exempted from the vaccination. Although there could be some impact from the assessment and surgical mask requirements, the administrative requirements, which offer or ensure vaccinations for patients and healthcare workers, are more relevant in terms of increasing vaccination coverage.

In that sense, many previous articles have studied either how mandatory vaccination increases actual vaccination rate or how influenza vaccination rate correlates with patient mortality (Gregory, Pritish and Robert 2005, Lone, et al. 2005, Aurora, et al. 2015, Robert, et al. 2010, Amanda, et al. 2006). For example, the paper by Udell et al. (2013) addressed that influenza vaccination may be associated with a lower risk of major adverse cardiovascular events, and that the highest-risk patients with more active coronary disease show a significant effect from treatment. While some public health law articles are focused on establishing model law formats by conducting comparative studies on each Hospital Influenza Vaccination Law (Alexandra and Marisa 2011), it is hard to find a study that estimates the actual impact of the laws on general public health. Moreover, there are not many studies that estimate the general impact of ensuring vaccination for healthcare workers on patient mortality, even though healthcare workers could be a major flu infection vector.

Poland et al. (2005) makes several points in terms of nosocomial transmission[1]. According to multiple studies, healthcare workers continue to work, even though they feel ill with influenza, which increases influenza exposure to patients and coworkers. Additionally, the influenza virus could be transmitted to general hospital visitors. Particularly, nosocomial influenza

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[1] This means that infection originated in the hospital.

is critical for the elderly and patients who are immunocompromised[2]. Influenza infection in these populations can often lead to complications that are "severe, prolonged, devastating illness, worst case in death or increased length of stay, and added costs" (Gregory, Pritish and Robert 2005). On the other hand, according to the CDC's explanation, the efficacy of the flu vaccine varies with an individual's health. Among healthy adults and youth in general, vaccination works well, while older people and people with certain chronic illnesses may develop less immunity than healthy groups after vaccination (CDC 2017), even though the influenza vaccination has a modest but significant effect on hospitalization prevention for persons over 50 years of age (Baxter, Ray and Fireman 2010). Therefore, it is important to vaccinate healthcare workers as well as patients.

Based on the above information, this paper will estimate the impact of ensuring flu vaccinations for healthcare workers on mortality from P&I. Administrative requirements for ensuring vaccination would increase overall healthcare workers' influenza vaccination rate, which reduces the probability of influenza infection. It would also reduce nosocomial transmission to patients and general hospital visitors, which can prevent them from becoming infected with influenza and developing severe complications. Eventually, such action decreases the number of flu-associated deaths, improves the public health environment and increases social welfare by reducing the number of sick leave days and medical costs.

Data description

The data was obtained from three US government websites; https://www.healthdata.gov/, https://www.census.gov/ and http://cdc.gov/. From healthdata.gov, I collected "Deaths in 122 U.S.

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[2] Having an impaired immune system and therefore incapable of having an effective immune response, usually as a result of disease.

cities - 1962-2016, weekly data" which reports the number of deaths from P&I and the overall number deaths regardless of cause. I merged the census data, which has state-level and city-level populations, from 2000-2015. Additionally, I obtained data for coverage rate of pneumonia vaccinations and influenza vaccinations from the CDC. In terms of data manipulation, I merged the above three datasets based on state and city name. The master data was "Deaths in 122 U.S. cities." The proportional mortality rate from P&I is my dependent variable. According to the Robert H. Friis (2010), proportional mortality rate is "the number of deaths within a population due to a specific disease or cause divided by the total number of deaths in the population during a time period such as a year."

Since proportional mortality doesn't take into account the total population, there are some limitations to using proportional mortality. Nevertheless, there are two reasons I continued to use proportional mortality rate. First, according to Raj Bhopal (2002), "Proportional mortality is a simple and potentially useful way of portraying the burden of a specific disease within a population, and the proportional mortality rate provides a way to compare populations." In that sense, proportional mortality rate for P&I would be good way to compare the burden of influenza within each city population. Second, mortality rate is calculated by year in general, but influenza has a month variation as well due to its seasonality. In that sense, there is a bias from limiting monthly variance when I aggregate the monthly number of deaths from P&I into the yearly data. However, I use the influenza mortality rate[3] to show the general trend by state and present the impact of the vaccination laws on the influenza mortality rate for the state level in my robustness check. The time period of the analysis is from 2000 to 2016 and the unit of analysis is city level. However, the time period was reduced to 2011-2015 when I placed in controls due to missing data. I have

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[3] https://www.cdc.gov/ophss/csels/dsepd/ss1978/lesson3/section3.html

four control variables: influenza vaccination coverage rate of over 65 years old, influenza vaccination coverage rate of age between 18 to 64 at high risk, pneumonia vaccination coverage rate of over 65 years old and pneumonia vaccination of ages between 18 to 64 at high risk. Although these controls are state level, I used these as proxy of city-level. These control variables are unlikely to be related to the mandatory vaccination for healthcare workers, but could be related by the dependent variable, proportional mortality from P&I. By including these control variables, I can estimate a more accurate impact of the treatment. The policy variable is the flu vaccination ensuring law for healthcare workers. Even though I focused on the ensuring provisions, administrative requirements for offering vaccination to healthcare workers could be used as a comparative figure. The policy is measured using a binary variable, ensuring flu vaccination for healthcare workers [1 = yes, 0 = no] and offering flu vaccination for healthcare workers [1= yes, 0 = no].

Analysis

Figure1 shows the general trend of state-level influenza mortality and the ratio of cities that introduced a mandatory vaccination law with either offering or ensuring provisions. Since 2000, the state-level influenza mortality rate has decreased. In 2007, California passed a law with an ensuring provision, affecting 11 cities of our sample. Therefore, the ensuring fraction jumped up to 0.09, 11 out of 121 cities. The average year when mandatory vaccination laws were introduced is 2008, as shown by the red line in Figure 1. After 2008, many states began to introduce mandatory vaccination with offering provisions until 2010. This rapid increase of implementation from 2008 to 2010 might be due to the 2009 flu pandemic. For instance, public opinion might push policy makers to legislate policies related to the flu. In those types of political situations, offering regulation has less of a political cost compared with ensuring, since ensuring regulations could arouse the public against healthcare workers that may infringe on policy effectiveness, health worker's privacy rights, freedom of choice and labor rights. From 2007 to 2008, there was a small increase in influenza mortality rate and a decrease in the mortality rate from 2008 to 2009. It is, however, hard to say whether the overall increase of Hospital Influenza Vaccination Laws led to the decrease after 2008, or if another factor or factors caused the overall decreasing trend of mortality. In addition, this is a yearly trend for mortality in 40 states, but influenza has a monthly seasonality that also needs to be considered. Moreover, there could be some unobservable individual city characteristics that affect mortality. Taking into account these limitations, this paper conducts two-way fixed effect analysis with city-level monthly data. For estimating monthly mortality variation, I used proportional mortality rather than mortality rate, which is based on a yearly period.

Estimating equation

$$\boldsymbol{Y_{i,t} = \beta x_{i,t} + \delta T_{i,t} + \theta_t + \alpha_i} + (\alpha_i * t) + \boldsymbol{\epsilon_{i,t}}$$

$$\begin{aligned}
&\boldsymbol{Proportional\ Mortality\ of\ Pneumonia}\ \&\ \boldsymbol{Influenza}_{(\boldsymbol{city,monthly})}\\
&\quad = \beta_1 \text{Flu vaccination coverage}(> 65)_{(\boldsymbol{city,monthly})}\\
&\quad + \beta_2 \text{Pneumonia vaccination coverage}(> 65)_{(\boldsymbol{city,monthly})}\\
&\quad + \beta_3 \text{Flu vaccination coverage at high risk}(18\text{yr to }64\text{yr})_{(\text{city},\boldsymbol{monthly})}\\
&\quad + \beta_4 \text{Pneumonia vaccination coverage at high risk}(18\text{yr to }64\text{yr})_{(\text{city},\boldsymbol{monthly})}\\
&\quad + \boldsymbol{\delta Healthcare\ worker\ mandatory\ vaccination}_{(\boldsymbol{city,monthly})} + \boldsymbol{Monthly}_{(\boldsymbol{fixed\ effect})}\\
&\quad + \boldsymbol{City}_{(\boldsymbol{fixed\ effect})} + (\text{unit} - \text{specific trends}) + \boldsymbol{\epsilon rror}_{(\boldsymbol{city,monthly})}
\end{aligned}$$

Note: $(\alpha_i * t)$; If including a unit-specific trend, would be based on parallel trend testing. If there is no parallel trend, then a unit-specific trend would be taken into account before the treatment trend.

According to Figure 2, it is difficult to hold a parallel trend assumption for an unbiased two-way fixed effect. This trend shows that there was an upward pre-treatment trend of mortality rate. Since the expected effect of the ensuring laws has a negative correlation with mortality rate, there could be some bias that underestimates the predicted impact of treatment. Based on this result, the unit-specific trend was included in the estimating equation to penalize this pre-treatment trend. In addition, due to missing values of the control variables, the time period was decreased and control variables were added. The possible time period of my final estimation model was from January 2011 to December 2015. Therefore, I show both models with the full time period and model from January 2011 to December 2015 until the final estimation model is completed.

[Table 1] Without the control variables, offering and ensuring laws both have a statistically significant positive correlation for each city's proportional mortality for 2000 to 2016. These results share a similar trend with the parallel trend, which shows a positive correlation with mortality change rate. Furthermore, even though these two results have a positive correlation, the magnitude is smaller for the ensuring law case than the offering law case. Although there is no statistically significant impact in 2011-2015, the ensuring treatment has a negative correlation with mortality.

[Table 2] When including the pneumonia vaccination coverage rate of patients over 65 years old and influenza vaccination coverage rate of patients over 65 years old, the time period in the analysis is January 2001 to December 2015 due to missing values. However, the control variables have a statistically significant negative correlation with mortality, which provides a more sensible coefficient than the previous result. A 1% increase of pneumonia vaccine coverage might reduce mortality from P&I by around 6%, and a 1% increase in flu vaccinations might reduce the mortality from P&I by 2~3%. In this model, while offering and ensuring laws are positively correlated, the magnitude of the ensuring law case is smaller than before. There is no statistically significant impact in 2011-2015.

[Table 3] After adding every control variable, the time period of the analysis is January 2011 to December 2015. According to the results, there is no statistically significant covariate without a clustering standard error. However, pneumonia vaccination and flu vaccination coverage for high risk groups have a negative correlation with mortality rate. Even though there are no statistically significant covariates, the ensuring provision has a negative correlation with mortality while the offering provision has a positive correlation with mortality. It could be interpreted that the upward pre-treatment trend has continued with cities under the offering provision.

I clustered standard error with the state level, since this is a state-level law and each city is under a certain state. Furthermore, each city is under other state-level public health laws that are not controlled in this model. Interestingly, after the clustering standard error on the state-level, the ensuring provision has a statistically significant effect. In general, clustering standard error increases standard error, but it is not always to be the case. Clustering reduces standard error and shows a statistically significant impact in this model, because the standard error has upward bias before clustering. Therefore, there is a statistically significant impact of ensuring provision. Holding other controls constant, a city under ensuring provision might has 0.5% less P&I mortality.

Although weighting could overestimate the covariates and increase the standard error, I weighted by city population since the proportional mortality rate does not take into account population size. Communicable diseases could be more easily spread when there are more human vectors of transmission. After weighting by city population, the estimated impact of ensuring provisions increases with a smaller standard error. Holding other controls constant, a city under an ensuring provision has 1% less P&I mortality. However, offering provisions have no statistically significant impact in every model.

[Table 4] Since all vaccination coverage controls are statistically insignificant, I change the flu vaccination coverage for over 65 years and pneumonia vaccination coverage for over 65years into treatment of treated impact by using the offering vaccination regulation for patients over 65 years old. From this, I only include the exogenous impact of vaccination for those over 65years. When I considered the exogenous impact of each vaccination, the flu vaccination coverage for those over 65 years old has a statistically significant impact. A 1% increase of flu vaccination coverage may reduce mortality from P&I by 42.9% within a 95% confidence interval. Although 1% increase of pneumonia vaccination coverage may increase mortality from P&I by 60% within a 90% confidence interval, it won't be a statistically significant impact within a 95% confidence interval. Therefore, we can think of the impact of the flu vaccination as a more reliable result in this regression model. After weighting by city population, these two controls lost their statistical significance as did the previous results. Regardless of using the treatment of treated and weighting, ensuring vaccinations for healthcare workers has a statistically significant impact.

Robustness check

[Table 5] For robustness check, I reduced the time period to the more relevant month period for the influenza season. According to the CDC, October to May is typically known as flu season and December to March is the peak flu season period. Although observation numbers decrease by limiting the time period, the impact of mandatory vaccinations for healthcare workers increases, which gives a sensible result regarding influenza seasonality. Without weighting, ensuring vaccination for healthcare workers may reduce 1% of mortality in the peak flu season period. I also aggregated the unit of analysis and time period into the state level and the yearly format using mortality rate instead of proportional mortality as the dependent variable. In this case, the ensuring provisions have a statistically significant impact both with and without the clustering standard error. The magnitude of impact is also higher than the regression model of the city level in the monthly period. Although other control variables are statistically significant without clustering, they become statistically insignificant after the clustering standard error.

Discussion

While this paper provides some statistically significant results, this model is not a perfect reflection of the real impact of Hospital Influenza Vaccination Laws, particularly Administrative Requirements for Ensuring Vaccination. First of all, the policy making process is not independent of other political circumstances, public opinion, economic growth and certain events in general. Therefore, without randomization, the error term includes some portion of unobservable factors that may correlate with the treatment effect. If we have enough budget, logistic network and management power without ethical issues, then we can estimate a more accurate impact of mandatory vaccination law for healthcare workers. For example, we can randomly select hospitals across the United States and divide them into three groups: control, offering and ensuring. We can perfectly control since there are no healthcare workers who get vaccinated in the control group and every healthcare worker has to be vaccinated in the ensuring group. For the offering group, we can regularly spread information that the hospital would offer vaccinations. Furthermore, patients' and the healthcare workers' individual characteristics, including immunization record, medical history, income and gender, have to be balanced. In this perfect scenario, we might have better estimation for the impact of mandatory vaccination for healthcare workers. However, it is ethically not allowed and almost impossible to control this research environment. Therefore, this regression model is based on a retrospective design and has an inevitable limitation for giving unbiased results compared to results from a randomization control trial.

In addition, as a law is a basic ground for establishing certain policy, implementing effective policy would be another issue. This means that there would be long causal chain from implementing the law to reducing deaths from P&I. Due to its long causal chain, the actual treatment effect goes down along with the causal process. This long causal chain also could lead unintentional statistically insignificant result in the model. For example, when some intermediate linkage is disconnected within a long causal chain, the regression model shows statistical insignificance even if treatment has a statistically significant impact at the early stage of causal change.

For estimating the equation side, I use the number of deaths from P&I as a proxy of influenza-associated deaths. However, this cannot capture all other possible associated deaths from influenza because R&C deaths (which include P&I deaths) estimation is more sensitive to describing flu-related deaths than underlying P&I deaths and is more specific than deaths from all causes. In that sense, the treatment effect could be underestimated in this regression model. In addition, I include control variables to get a more an accurate estimation, but I lost time variance due to the missing values. According to my data, there would be a low possibility for a huge variance of vaccine coverage over time, and some possibility that my model lost effect due to missing values. While I controlled for unobservable individual city characteristics by using the fixed effect and clustering standard error at the state level, there still could be some omitted variable bias. Finally, this regression model does not take into account ethical issues such as privacy rights, freedom of choice and labor rights of healthcare workers.

Conclusion

Influenza is a common but easily neglected communicable disease that generates considerable cost in terms of health and economy. In that sense, the US government has invested efforts to increase flu vaccination because it has been regarded as the most effective way to prevent the spread of influenza. Nevertheless, flu vaccination rate has not met the CDC goal due to its public good feature. Along with this low public vaccination rate, the importance of vaccination in healthcare settings has been increasing, since immuno-compromised people in hospitals are the most vulnerable group for flu-associated complications and deaths. In response, several states have passed Hospital Influenza Vaccination Laws, which enforces mandatory vaccination offerings or ensuring requirements for patients and healthcare workers. In terms of mandatory flu vaccinations, several studies have indicated that mandatory vaccination laws increase take-up rate. In addition, many studies have dealt with the impact of flu vaccination in regards to various kinds of morbidity and mortality. However, there are not many studies that estimate correlation between mandatory vaccination law and flu associated mortality. This paper used a two-way fixed effect with unit-specific trend to examine an impact of mandatory flu vaccination for healthcare workers on flu associated deaths, particularly deaths from pneumonia and influenza. While each state has different provisions and details in terms of Hospital Influenza Vaccination Laws, the paper focused on the provision of mandatory ensuring vaccinations for healthcare workers, as the ensuring provision has more relevance to increasing vaccination among healthcare workers who could be major influenza transmission vectors. Furthermore, the efficacy of vaccination is low for immuno-compromised people compared to healthy people.

According to the regression analysis, ensuring vaccination for healthcare workers has a statistically significant impact, while offering vaccination for healthcare workers is statistically insignificant. With the inclusion of control variables, a city that is under an ensuring provision has a 0.5% less proportional mortality from pneumonia and influenza. This impact size would be increased to 1% when the model is weighted by city population. Robust check results show that the model well-reflects actual influenza seasonality and provides sensible results even if the unit of analysis and time period is aggregated into state-level and yearly. Particularly, the later robust model used general mortality rate as the dependent variable and the coefficient of ensuring treatment is increased compared to proportional mortality rate with city-level in a monthly period.

Based on this result, an Administrative Requirements for Ensuring Vaccination to healthcare workers provision would be better for reducing flu-associated deaths rather than Administrative Requirements for Offering Vaccination to healthcare workers. Therefore, it would be reasonable to think that adding an ensuring provision rather than an offering provision is more effective for preventing flu-associated deaths. However, this paper did not study the impact of assessment requirements and surgical mask requirements. In that sense, there could be better impact from those two other provisions. Studying these two other provisions would be helpful to understand the overall impact of Hospital Influenza Vaccination Laws in the future. Furthermore, even though the regression model includes control variables and controls unobservable characteristics and pre-treatment trends by using the two-fixed effect and including a unit-specific trend, still there could be some biases, such as the omitted variable bias. Also, the time period is only four years due to missing values. The regression result may be improved if we have better coverage rates data. In addition, this paper does not consider cost-benefit and cost-effect analysis, and thus implementing policy would be different in a real world setting. This is particularly so as many healthcare workers may feel uncomfortable with ensuring requirements and assessment requirements due to their insufficient evidence for effectiveness, health worker's privacy rights, freedom of choice and labor rights. Despite these limitations, I hope this paper helps to promote a constructive discussion for preventing influenza and to act as an informative reference for actual public health policy making.

Appendix [TABLE]

TABLE 1

	From 2000/01 - 2016/10		From 2011/01 - 2015/12	
VARIABLES	Proportional mortality	Proportional mortality	Proportional mortality	Proportional mortality
Mandatory offering to healthcare worker	0.0106***		0.00685	
	(0.00165)		(0.00672)	
Mandatory ensuring to healthcare worker		0.00825***		-0.00480
		(0.00204)		(0.00619)
City Fixed Effect	YES	YES	YES	YES
Time Fixed Effect	YES	YES	YES	YES
Unit trend specification	YES	YES	YES	YES
Constant	7.525***	7.525***	4.886	4.886
	(1.130)	(1.130)	(6.024)	(6.024)
Observations	24,205	24,205	7,135	7,135
R-squared	0.447	0.447	0.556	0.556

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 2

	From 2001/01-2015/12		From 2011/01-2015/12	
VARIABLES	Proportional mortality	Proportional mortality	Proportional mortality	Proportional mortality
Pneumonia vaccine coverage (>65yrs)	-0.0551***	-0.0572***	0.0137	0.0108
	(0.0131)	(0.0131)	(0.0290)	(0.0290)
Flu vaccine coverage (>65yrs)	-0.0265***	-0.0161*	0.00354	0.00383
	(0.00951)	(0.00928)	(0.0152)	(0.0152)
Mandatory offering to healthcare worker	0.0118***		0.00693	
	(0.00277)		(0.00674)	
Mandatory ensuring to healthcare worker		0.00526*		-0.00473
		(0.00317)		(0.00623)
City Fixed Effect	YES	YES	YES	YES
Time Fixed Effect	YES	YES	YES	YES
Unit trend specification	YES	YES	YES	YES
Constant	4.701***	4.695***	4.874	4.875
	(1.317)	(1.318)	(6.041)	(6.041)
Observations	14,226	14,226	7,003	7,003
R-squared	0.499	0.499	0.553	0.553

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

TABLE 3

	Without cluster		With cluster		With cluster + weight	
VARIABLES	Proportional Mortality		Proportional Mortality		Proportional Mortality	
Pneumonia vaccine coverage (>65yrs)	0.0124	0.0107	0.0124	0.0107	-0.00581	-0.00832
	(0.0296)	(0.0296)	(0.0357)	(0.0361)	(0.0245)	(0.0243)
Pneumonia vaccine coverage at high risk (18~64yrs)	-0.0299	-0.0229	-0.0299	-0.0229	0.0117	0.0148
	(0.0293)	(0.0286)	(0.0310)	(0.0302)	(0.0227)	(0.0215)
Flu vaccine coverage (>65yrs)	0.00859	0.00835	0.00859	0.00835	0.0194	0.0202
	(0.0154)	(0.0154)	(0.0132)	(0.0131)	(0.0158)	(0.0158)
Flu vaccine coverage at high risk (18~64yrs)	-0.0145	-0.0157	-0.0145	-0.0157	-0.00669	-0.00692
	(0.0111)	(0.0111)	(0.0113)	(0.0111)	(0.0130)	(0.0129)
Mandatory offering to healthcare worker	0.00791		0.00791		0.00736	
	(0.00693)		(0.00747)		(0.00636)	
Mandatory ensuring to healthcare worker		-0.00474		-0.0047***		-0.0093***
		(0.00623)		(0.00144)		(0.00125)
City Fixed Effect	YES	YES	YES	YES	YES	YES
Time Fixed Effect	YES	YES	YES	YES	YES	YES
Unit-specific Trend	YES	YES	YES	YES	YES	YES
Constant	4.887	4.887	4.887***	4.887***	4.849***	4.849***
	(6.040)	(6.040)	(0.0319)	(0.0317)	(0.0204)	(0.0199)
Observations	7,003	7,003	7,003	7,003	7,003	7,003
R-squared	0.554	0.554	0.554	0.554	0.698	0.698

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 4

VARIABLES	Treatment of Treated Flu vaccine coverage (>65yrs)	 Pneumonia vaccine coverage (>65yrs)	Weight X Proportional Mortality	Weight O Proportional Mortality
Mandatory offering to patient (> 65yrs)	-0.00441	-0.00974***		
	(0.00501)	(0.00365)		
Exogenous impact of pneumonia vaccination coverage (>65yrs)			0.591*	0.625
			(0.350)	(0.456)
Pneumonia vaccine coverage at high risk (18~64yrs)			-0.0179	0.0286
			(0.0274)	(0.0208)
Exogenous impact of flu vaccination coverage (>65yrs)			-0.429**	-0.397
			(0.183)	(0.238)
Flu vaccine coverage at high risk (18~64yrs)			-0.0135	-0.00503
			(0.0108)	(0.0135)
Mandatory ensuring to healthcare worker			-0.00491***	-0.00870***
			(0.00128)	(0.000770)
City Fixed Effect	YES	YES	YES	YES
Time Fixed Effect	YES	YES	YES	YES
Unit specific trend	YES	YES	YES	YES
Clustering Standard Error	City	City	State	State
Constant	0.658***	0.589***	4.765***	4.674***
	(0.00212)	(0.00200)	(0.365)	(0.475)
Observations	18,305	17,240	7,003	7,003
R-squared	0.770	0.861	0.554	0.698

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 5

VARIABLES	Jan. ~ Dec. Proportional Mortality	Oct. ~ May Proportional Mortality	Dec. ~ Mar. Proportional Mortality	2011-2015 Mortality	2011-2015 Mortality
Pneumonia vaccine coverage (>65yrs)	0.0107	-0.0293	-0.0501	-0.0784***	-0.0784
	(0.0361)	(0.0373)	(0.0451)	(0.0125)	(0.120)
Pneumonia vaccine coverage at high risk (18~64yrs)	-0.0229	-0.0336	0.00379	0.0447***	0.0447
	(0.0302)	(0.0316)	(0.0532)	(0.0119)	(0.0901)
Flu vaccine coverage (>65yrs)	0.00835	0.0142	-0.00410	0.0201***	0.0201
	(0.0131)	(0.0153)	(0.0279)	(0.00657)	(0.0471)
Flu vaccine coverage at high risk (18~64yrs)	-0.0157	0.000839	0.00488	-0.0356***	-0.0356
	(0.0111)	(0.0109)	(0.0233)	(0.00465)	(0.0388)
Mandatory ensuring to healthcare worker	-0.00474***	-0.00483***	-0.0115***	-0.0095***	-0.00954***
	(0.00144)	(0.00153)	(0.00241)	(0.00262)	(0.00311)
Fixed effect	City level	City level	City level	State level	State level
Time Fixed effect	Monthly	Monthly	Monthly	Yearly	Yearly
Unit-specific trend	YES	YES	YES	YES	YES
Cluster Standard Error, State-level	YES	YES	YES	NO	YES
Constant	4.887***	6.358***	2.770***	-6.755***	-6.755
	(0.0317)	(0.0338)	(0.0394)	(2.141)	(4.052)
Observations	7,003	4,668	2,334	7,022	7,022
R-squared	0.554	0.565	0.565	0.990	0.990

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, *
p<0.1

Appendix [Figure]

Figure 1

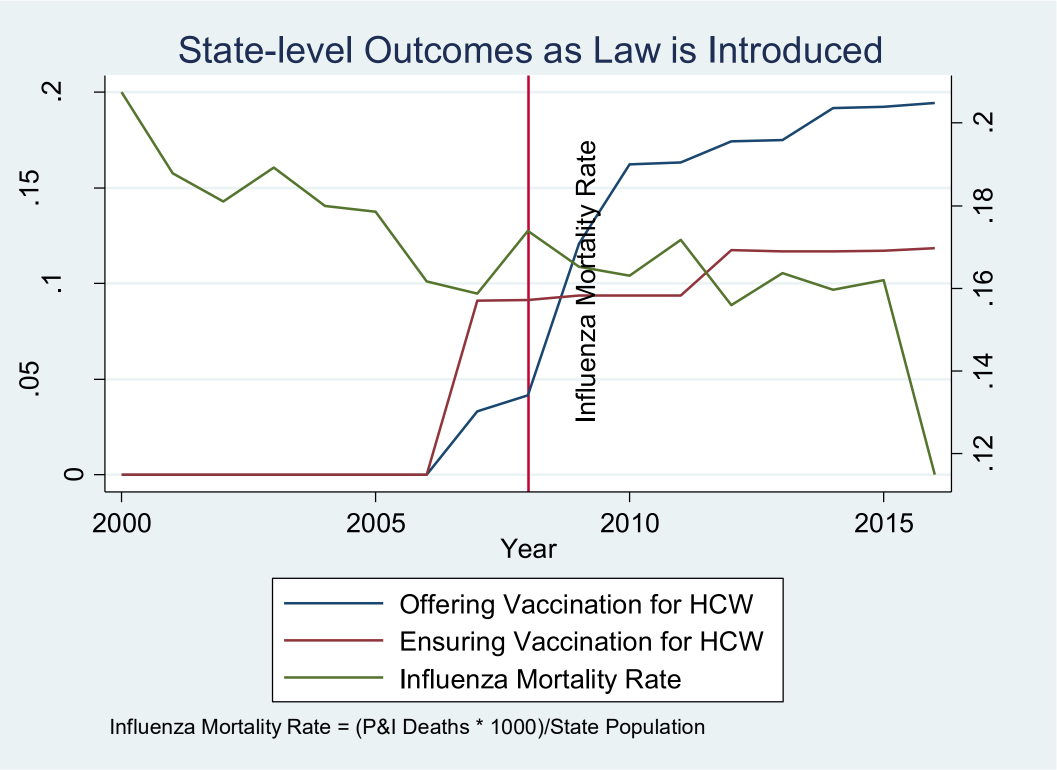
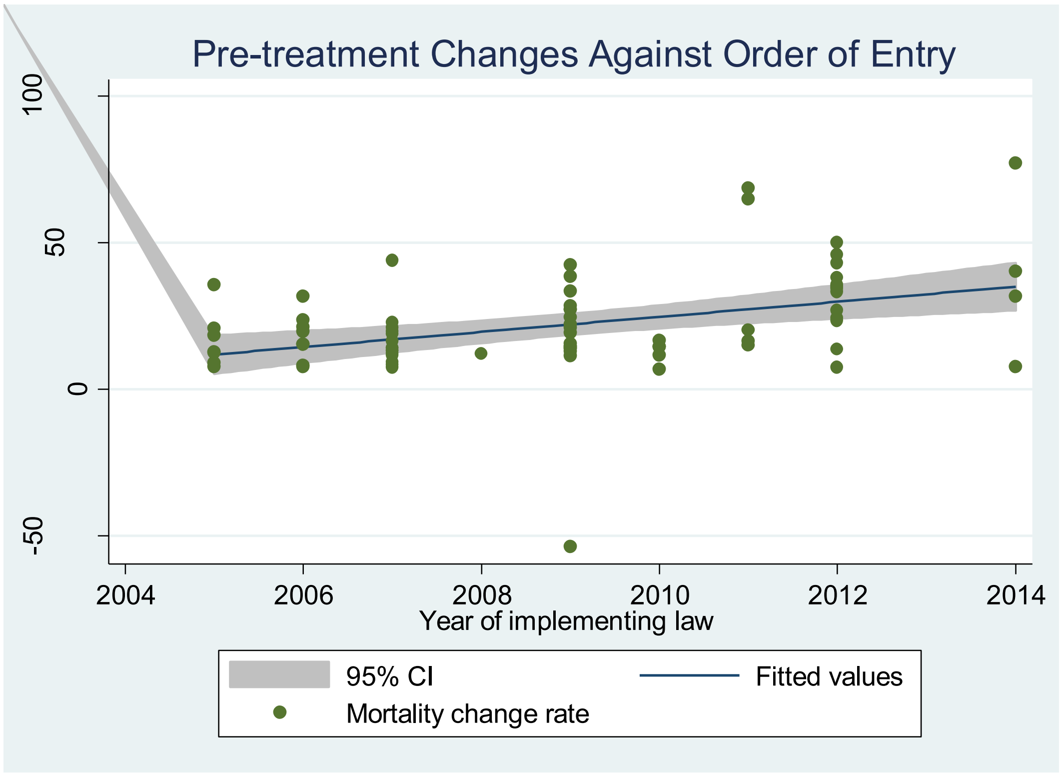


Figure 2


Pre-treatment Changes Against Order of Entry
100
50
0
-50
2004
2006
2008
2010
2012
2014
Year of implementing law
95% CI
Fitted values
Mortality change rate

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