Flu Vaccines on College Campuses: Survey of Challenges and Local Intervention

Michael Wang Adviser: Prof. Howard Forman Yale Economics Senior Essay

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Abstract

College campuses are particular causes for concern each flu season because of the close and constant proximity of community members. Limited existing research suggests that, like the general population, this subpopulation is undervaccinated, and inaccurate perception of the safety, efficacy, and necessity of the vaccine plays a large part. In this paper, we introduce a simple cost-benefit model of the decision to obtain the vaccine and use it to motivate a research design similar to those of health disparities work. We administer an attitude survey to the Yale community, run a publicity campaign aimed at increasing flu vaccine uptake, and obtain uptake data from peer institutions to estimate the impact of the intervention through a difference-in-differences approach. Although these efforts were limited in scope, and a statistically significant effect was not found, we corroborated existing results about college flu vaccines and identified substantial variation in university investment and policy towards vaccination.

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1 Introduction

1.1 Background

Flu Vaccines in the US

Since 2010, the Centers for Disease Control and Prevention (CDC) has recommended the annual influenza vaccine as the single most important intervention for preventing the flu for all individuals six months of age and older [1]. This recommendation is based on a preponderance of evidence that suggests that the vaccine, while not perfect, is generally effective at immunizing against a disease that causes significant morbidity and mortality [2]. Despite the strength of the CDC's guideline, vaccine uptake in the American public has been very low. CDC data estimate that uptake rates in the US have held around 45% nationally for the past five years, a far cry from the national target of 70% by 2020 [3].¹

Existing research on flu vaccines focuses mostly on high-risk groups and health care workers, and more recently on the H1N1 vaccine developed in response to the 2009 flu pandemic, with only a few studies targeting healthy adults. Although simple in design, the results of these efforts do point to a common theme of public perception - that is, despite the conclusive body of evidence concerning flu vaccine efficacy and safety, there exists substantial variance in how effective and safe people *think* the vaccine is. One survey of university workers and corporate employees found an association between the decision to vaccinate and perceived effectiveness of the vaccine and likelihood of side effects [4]. Another national survey of adults found that during the H1N1 pandemic of 2009-2010, people on average considered H1N1 a more serious disease than the seasonal flu but perceived the H1N1 vaccine, which was manufactured similarly to the seasonal vaccine, to be less safe [5].

Within this context, the college campus is a particularly interesting subset to study for several reasons. First, the close and constant proximity between students, faculty, and staff on campus makes such a community highly susceptible to local outbreaks of infectious diseases such as the flu. Second, for the generally young and healthy university student population, flu mortality is not a large concern, and their priorities may differ from those of the general population. Third, misconception may be less pervasive in institutions of higher learning than average. Fourth, as will be explored in this paper, there is a remarkable amount of heterogeneity in how universities offer, charge for, and publicize the flu vaccine.

College Campuses

The American College Health Association (ACHA) conducts a survey each semester called the National College Health Assessment (NCHA), which includes questions about cold/flu morbidity and flu immunization. According to voluntary respondents to this survey, approximately 45% caught cold and/or flu in 2015-16, and of those, about 30% reported negative effects on academic work [6]. Flu vaccine uptake among NCHA respondents was close to 45% in recent years, which matches the national rate.

 $^{^180\}mathchar`-90\%$ for certain high-risk subgroups

These numbers agree with the results from a series of studies at The University of Minnesota, St. Paul about flu vaccinations on campus. A 2002-03 survey of 3000 found that almost 40% of respondents reported experiencing at least one influenza-like illness (ILI) in the past year, resulting in thousands of school and work days missed and poor performance on assignments and tests [7]. A later pooled analysis of four consecutive flu seasons found that students who were vaccinated experienced significantly fewer ILI than those who were not, but the uptake rate was only about 30% [8]. These studies provide evidence that the flu causes significant morbidity in the college population, that the flu vaccine is effective for this population, and that the vaccine is severely underutilized.

Several organizations have undertaken efforts to change the status quo of flu vaccine uptake at the college level. In 2016, the three-year New York State Higher Education Immunization Collaborative began [9]. This initiative, led by New York University with support from the New York State and New York City governments, is taking a quality improvement approach to increasing uptake rates. Participating institutions follow a common schedule intended to improve a set of "process measures" backed by quality control literature. Examples include offering flu vaccination clinics at multiple locations and times, recommending the flu vaccine at all UHS visits, and setting up both patient and provider-side reminders in the electronic medical record (EMR). In a common schedule, participants cycle through several phases of intervention and reflection to share knowledge and experience and adjust efforts in response to feedback. This approach focuses on implementation and thus relies on a robust evidencebased literature.

That same year, the National Foundation for Infectious Diseases (NFID) held a summit on the issue of influenza vaccination on college campuses, culminating in a report of recommendations for colleges [10]. The organization advocates for increased research efforts in this area, as the problem is less well-defined and well-quantified than that for groups traditionally considered high-risk, and increased sharing and dissemination of knowledge. It also encourages colleges to unite institutional and student efforts to make the vaccine accessible and encourage community members to obtain it.

1.2 Motivating Models

Externalities

In economics, vaccines are the standard example of the concept of positive externality. An externality is an effect on society that an individual does not take into account when deciding whether to consume a good or perform an action. If someone obtains the flu vaccine, that person is much less likely to spread the disease, which is a benefit to all other members of society. But since this social benefit does not accrue directly to the person and therefore does not factor into personal decision making, the natural tendency of society is to underutilize the vaccine relative to the ideal uptake level. The economic solution to such inefficient welfare effects of positive externalities is to offer subsidies to encourage uptake at ideal levels. Indeed, the Affordable Care Act (ACA) identifies the vaccine as preventive care that insurance plans must offer free without copay, and many University Health Services (UHS) offer flu vaccines

to their communities for free.

Herd Immunity

In the clinical literature, externality is integrated into a related concept called herd immunity. Imagine that someone infected with the flu spreads it, on average, to R_0 people. If $R_0 > 1$, then the population is prone to a disease outbreak or pandemic. But suppose a proportion p of the population receives a vaccine with effectiveness e; then the infected can only spread the flu to the proportion of the population that remains susceptible, (1 - pe), and herd immunity is reached when enough of the population is vaccinated that outbreak does not occur, i.e.

$$R_0(1-pe) < 1 \Leftrightarrow p > \frac{1-1/R_0}{e}$$

This inequality shows that herd immunity-level vaccination is an increasing function of how infectious the disease strain is and a decreasing function of how effective the vaccine for the disease is, which matches intuitive expectations. In terms of externalities, it represents a substantial social benefit and explains the CDC's strong recommendations.

There is evidence that vaccination at US target levels would result in herd immunity against influenza. The CDC's studies and literature review estimate that seasonal flu vaccine effectiveness usually ranges from 50-60% [11]. A reasonable estimate of the R_0 of seasonal flu based on available evidence is 1.2-1.4 [12]. Putting these estimates together, we have

$$p = \frac{1 - 1/(1.2)}{.60} = 0.28$$

as a lower bound and

$$p = \frac{1 - 1/(1.4)}{.50} = 0.57$$

as an upper bound - both well below 80%.

But the R_0 estimate is an average, and we would naturally expect it to be higher in more concentrated environments. Indeed, Plans-Rubio et al approximate a 75% upward adjustment to R_0 for "close settings" such as schools and health care centers [13]. For the purpose of estimation, let us assume that college campuses are half as concentrated as close settings relative to the average and apply a 37.5% upward adjustment to R_0 . This yields

$$p = \frac{1 - 1/(1.2 * 1.375))}{.60} = 0.66$$

as a lower bound and

$$p = \frac{1 - 1/(1.4 * 1.375)}{.50} = 0.96$$

as an upper bound; much of this interval now lies above 80%. But in this simple, static model, we are ignoring more subtle effects such as the fact that when vaccinated individuals contract the flu, they tend to experience a shorter and more mild disease course than unvaccinated individuals [3].

There is a fuller theoretical model of the spread of flu through a closed college campus in the literature, developed by the same lead researcher of the aforementioned University of Minnesota, St. Paul studies, Dr. Kristin Nichol [14]. In this model of disease course, one individual is infected on Day 1 and, during a set infectious period, spreads the disease through the community, some proportion of which may be vaccinated on Day 1 or during the flu season. In their baseline specification, as pre-season vaccination rates increase from 20% to 60%, the percentage of the community that is affected drops from 45% to <1%, indicative of herd immunity (although it should be noted that Nichol et al use an optimistic vaccine effectiveness rate of 80%). Even when some of the vaccination occurs later in the season, it has a substantial effect of reducing disease spread.

These herd immunity results give an idea how of think about the positive externality effects of vaccines - namely that there is some marginal social benefit of getting vaccinated that becomes very large when a critical threshold of uptake rate is crossed. The Nichol et al model also supports the intuition of providers (and CDC recommendation) to vaccinate throughout the flu season.

Cost-Benefit Analysis

As a motivating thought experiment for this project, consider the following scenario: on Oct. 1, a lever appears in every member of a college community's room. If these individuals pull it, they gain the single effect of 50-60% resistance to the influenza virus for one year. In such a situation, benefits are positive and costs are zero, so uptake would surely be near 100%. The reasons why uptake is not 100% must be rooted in why real life is unlike this thought experiment. Monetary cost is unlikely to be a significant factor because of ACA provisions and free vaccine policies. The vaccine itself is negligibly risky with mostly mild side effects and offers measurable resistance to the flu [15]. But people may have imperfect information about the vaccine; they may feel it is not effective or believe it can cause adverse effects such as muscle and joint pain, the flu itself, or even autism. Or people may be factoring in the logistics of receiving the vaccine as costs; they may be unaware of flu clinic times and locations, believing they must make an appointment, or perceive the travel and wait time as inconvenient.

We have established the possibility that people might view the benefits of the vaccine its efficacy and the avoided cost of getting sick - differently, and they might view the costs of the vaccine - its safety and the inconvenience of obtaining it - differently as well. To formalize this cost-benefit framework, let us model Benefits (B) and Costs (C) of obtaining a flu vaccine as a bivariate normal distribution. In particular, let each member i of a college community face an ordered pair of benefits and costs (b_i, c_i) drawn from the population distribution defined by

$$B \sim N(\mu_B, \sigma_B^2),$$

$$C \sim N(\mu_C, \sigma_C^2),$$

$$corr(B, C) \equiv \rho \neq 0$$

If $b_i > c_i$, individual *i* will obtain the vaccine, and the proportion of the population for which this is true is the vaccine uptake rate. To be exact,

$$B - C \sim N(\mu_B - \mu_C, \sigma_B^2 + \sigma_C^2 - 2\rho\sigma_B\sigma_C) ::$$

uptake = normalcdf_{B-C}(0, \infty)

Intuition tells us that B and C are likely to be negatively correlated because of an information effect. That is, someone who knows the effectiveness of the flu vaccine and perceives a high benefit of vaccination is less likely to be subject to a misconception such as the possibility that the vaccine itself can cause influenza, and therefore will tend to perceive low costs of vaccination. If we make the simplifying assumption that Benefits and Costs are perfectly negatively correlated ($\rho = -1$), then we can represent the relationship between policy and uptake with a nice figure:



In this figure, the Benefits and Costs distributions are shown together. Because of our assumption of a perfect negative relationship, we know for each individual their entire ordered pair given one of the two values, allowing us to visually depict the portion of the population that does not obtain the vaccine (shaded in gray).

We can think of university policy as a shifter of Costs from this baseline. If a UHS requires people to make appointments or complete insurance paperwork to be vaccinated, Costs for every member of that college community are higher. Conversely, if a UHS offers many convenient flu clinics and engages in publicity and reminders to remove the barrier of remembering to get vaccinated, Costs for that college community are lower.

Similarly, patient education can be considered a shifter of both Benefits and Costs. If a

community learns how effective the flu vaccine is or is altruistic and learns about herd immunity, then Benefits are higher. Conversely, if a community learns that the vaccine causes neither flu nor autism, Costs are lower.

If we picture what happens to the size of the shaded area when B and C shift around, we arrive at the intuitive result that an increase in Benefits or a decrease in Costs increases uptake. Because each individual only makes an all-or-nothing decision, we cannot empirically observe these distributions. But as a theoretical framework, they can help us think about what the effects of interventions and policy changes are; every marginal effort that increases Benefits and/or decreases Costs causes a marginal portion of the population to cross its threshold and decide to obtain the vaccine, and the cumulative effects of multiple changes are additive. Through surveys and experiments, one can target changes that are likely to result in the largest shifts.

1.3 Research Design

This research project is based off the canonical designs of health disparities research (and, although developed independently of the NFID report, matches well with its guidelines). In health disparities work, a certain group possibly underutilizes medical care or experiences increased disease burden relative to another group. The three directions of inquiry are often blended in actual work but are perhaps best understood as a sequence. First, research identifies and quantifies a disparity through medical chart reviews and surveys. Once there is evidence for the existence of a disparity, researchers search for factors that predict the disparity at the provider level through quality measures and at the patient level through surveys and focus groups. Finally, efforts turn to alleviating the disparity through experimental interventions.

Analogously, in this work the population (Yale University) underutilizes medical care (the flu vaccine) relative to a target (the Healthy People 2020 level of vaccination). We first elucidate the important reasons why Yalies do and do not receive the flu vaccine with an attitude survey. Next, we implement an intervention informed by the factors precluding screening identified in the survey. Analyzing vaccination records from Yale alone is not enough to estimate the impact of the intervention because other factors, such as media exposure and secular trends, could cause vaccine uptake to vary year to year independently of the intervention. We therefore obtain data from peer institutions; to the extent that uptake rates at other universities capture these external effects, we can subtract the difference in uptake observed at those universities from before to after the intervention from the analogous difference observed at Yale.

This difference-in-differences (DiD) approach depends crucially on the Parallel Trend Assumption - that is, the assumption that what would have happened at Yale in the absence of the intervention is what did happen at other universities, or equivalently that the uptake rate difference observed at Yale is the sum of the intervention effect we want to measure and other effects that are reflected in the data for other universities. This assumption seems reasonable as long as flu vaccine policy and publicity does not change in the years of interest at comparison institutions. In this way, uptake data from peer institutions allows us to estimate the impact of the intervention.

Additionally, this data provides us with some original observations of uptake rates. Finally, collation of information on university websites and conversations with UHS administration at peer institutions provide a sense of differences in policy and practice between universities with respect to the flu vaccine.

2 Attitude Survey

2.1 Methods

The attitude survey, intended to gauge campus opinion on the flu and the flu vaccine, was delivered through Qualtrics in late October 2016. Respondents were first asked about:

- Affiliation (undergraduate, graduate or post-graduate, faculty, staff)
- Receiving a vaccine the previous year (at Yale flu clinic, elsewhere, no, unsure)
- Flu diagnosis or flu-like symptoms the previous year (yes, no, unsure)

They were then asked to rank the following statements on the five-point Likert (strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree) scale:

- 1. Getting the flu would be a burden on my workload and productivity.
- 2. The yearly flu vaccine is an effective way to reduce my chance of getting the flu.
- 3. There is a chance I could get the flu from the vaccine itself.
- 4. There is a chance I could contract autism or another serious disease from the vaccine.
- 5. There is a chance I could experience side effects from the vaccine that would impact my workload and productivity.
- 6. I know or can easily find out where and when to go to get vaccinated.
- 7. At least one flu clinic location is convenient for me.
- 8. There is a time during flu clinic hours that is convenient for me.
- 9. The wait time at flu clinic is reasonable.

Finally, there was an optional open field for comments.

Because Yale Health offers the flu vaccine to the entire community, a university-wide message was the ideal reach for the survey. Unfortunately, due to institutional policy, this was not possible. Instead, the survey was distributed to several student lists we had access to: Jonathan Edwards College non-freshmen, a residential college representing an approximately random sample of the undergraduate population; the Student Technology Collaborative, an organization of student workers, staff managers, and advisers that handle all issues related to student computing; and the Yale Economics Department, including individuals of all affiliations.

2.2 Results

Out of 250 people who began a survey, 229 completed it, of which 174 were undergraduate, 25 were graduate or post-graduate, 18 were faculty, and 12 were staff. Figures 2 and 3 show responses to questions 2 and 3, about being vaccinated and experiencing ILI within the past year, respectively. Figure 4 shows the same responses converted to binary percentages.

Figure 2: Flu Vaccine in the Past Year







Figure 4: Percentage Flu Vaccine, ILI in the Past Year

A small majority of undergraduate respondents received the flu vaccine in the past year, but approximately one-third of the vaccinations occurred outside of the Yale flu clinics. This may not be a cause for concern for interpretation of medical records data as uptake rates because, based on the wording of the choices, vaccines obtained at a Yale Health appointment could be part of this category, and freshman respondents did not have access to a flu clinic² - so internal Yale Health uptake data could still capture the large majority of total vaccinations. Slightly less than half of graduate respondents received the vaccine, and the majority of faculty and staff respondents received the vaccine.

16% of undergraduate and graduate respondents experienced ILI in the past year, while only one employee reported the same, although sample sizes are small for employees and relatively small for all subgroups except undergraduates. Due to sample size and survey reach limitations, these respondent statistics cannot be generalized in any way, but there is enough student-level data to run correlation tests with attitudes and attempt to verify the associations seen in the literature. The remainder of the analysis will focus on undergraduates.

The following table summarizes undergraduate attitude survey responses and selected subpopulation breakdowns by condensing the five-point Likert scale into three categories (questions reproduced below):

q1 Getting the flu would be a burden on my workload and productivity.

q2 The yearly flu vaccine is an effective way to reduce my chance of getting the flu.

q3 There is a chance I could get the flu from the vaccine itself.

q4 There is a chance I could contract autism or another serious disease from the vaccine.

q5 There is a chance I could experience side effects from the vaccine that would impact my workload and productivity.

q6 I know or can easily find out where and when to go to get vaccinated.

q7 At least one flu clinic location is convenient for me.

q8 There is a time during flu clinic hours that is convenient for me.

q9 The wait time at flu clinic is reasonable.

Donulation	Deenenee	Cost and Benefit		Side Effects			Flu Clinics			
Population	Response	q1	q2	q3	q4	q5	q6	q7	q8	q9
	Agree	84%	75%	26%	2%	38%	93%	82%	70%	50%
All	Disagree	13%	11%	60%	95%	44%	4%	3%	7%	5%
	Neutral	2%	14%	14%	2%	18%	3%	14%	22%	45%
	Agree	83%	92%	17%	0%	39%	95%	88%	85%	90%
Clinic	Disagree	17%	3%	66%	100%	37%	3%	3%	2%	2%
	Neutral	0%	5%	17%	0%	24%	2%	8%	14%	8%
	Agree	82%	68%	32%	4%	39%	96%	89%	79%	64%
Sick	Disagree	18%	14%	46%	96%	46%	4%	4%	11%	0%
	Neutral	0%	18%	21%	0%	14%	0%	7%	11%	36%

 Table 1: Undergraduate Attitude Survey Responses

"Clinic" refers to respondents who attended a Yale flu clinic in the past year. "Sick" refers to respondents who reported experiencing an ILI in the past year.

 2 Efforts were made to exclude freshmen from the reach of the survey for this reason, but some may still have completed it.

Questions 3 and 4, asking about the possibility of contracting flu or autism from the vaccine, are objective, since the scientific consensus is that neither is possible [15]. Question 5, about the possibility of serious side effects, was worded ambiguously, as there is a small risk of serious effects from any medical treatment, so unfortunately the responses are uninterpretable.

Overall, the majority of respondents agreed the flu affects productivity, and the vaccine would be beneficial, the latter especially in the "Clinic" subpopulation (92% vs 75%). Misconception about the vaccine causing flu was high, with over a quarter of respondents agreeing – fewer in the "Clinic" subpopulation and more in the "Sick" subpopulation – but misconception about the vaccine causing autism was virtually nonexistent. Respondents generally found the flu clinics to be accessible and convenient, especially among those who had actually been to one.³

We can formalize the putative relationships between subpopulations and attitudes with standard correlation testing on a 1-5 Likert scale:

	Cost and Benefit		Side Effects			Flu Clinics			
Subpopulation	q1	q2	q3	q4	q5	q6	q7	q 8	q9
Clinia	-0.01	0.30*	-0.08	-0.09	0.04	0.06	0.15*	0.26*	0.55*
Clinic	(0.89)	(0.00)	(0.26)	(0.17)	(0.60)	(0.45)	(0.04)	(0.00)	(0.00)
Siek	-0.03	-0.10	0.07	0.03	-0.08	-0.03	0.02	-0.02	0.15*
SICK	(0.74)	(0.23)	(0.38)	(0.69)	(0.35)	(0.67)	(0.81)	(0.80)	(0.04)

Table 2: Subpopulation Correlation Testing

Values are correlation coefficients between subsets of undergraduate respondents defined above, coded as dummy variables, and survey responses on the 5-point Likert scale, with p-values in parentheses. Starred coefficients are statistically significant at the 5% level.

As identified with the simple percentage table, respondents who attended a Yale flu clinic in the past year tended to perceive the vaccine as beneficial and have a high opinion of flu clinic availability and wait time. There is a barely significant correlation between respondents who experienced ILI in the past year and perception of flu clinic wait time, but there is not a clear link between these two characteristics, and given that eighteen hypotheses were tested, this could reasonably have arisen by chance.

Many of the voluntary comments expressed a sentiment that obtaining the flu vaccine, while possibly beneficial, was unnecessary - or, relatedly, that it was too much of a hassle to remember and travel to a flu clinic. This plays into the motivating observation that a college population may be less concerned about morbidity from influenza despite the risks of close proximity to others. For this reason, the promotion campaign included reference to the social benefit of vaccination.

 $^{^{3}}$ For the flu clinic questions, we expected many neutral responses from respondents who were unfamiliar with their operation.

3 Intervention

Because of the delays in distributing the survey, we were only able to publicize two clinics, held November 9 and December 6 at the Yale Health Center. A few days before these clinics, we made Facebook events which were posted in undergraduate class groups. On the days of the clinics, approximately thirty posters were hung at heavily-trafficked places on central campus such as classroom buildings, libraries, and intersections. Both publicity media focused on the social benefit of the vaccine and the convenience of the flu clinics.

Figure 5: Facebook Event 12/6





Find normal walk-in hours at http://yalehealth.yale.edu/immunization

4 Uptake Data

4.1 Methods

Uptake data was requested by email to directors and administrators of UHS at Yale and peer institutions. Specifically, data was requested for the period August 1 to December 31 of the years 2014, 2015, and 2016. We only considered the fall semester because the intervention would be completed during this time. We requested number of vaccines administered and total number of people eligible, stratified by affiliation (undergraduate, graduate, faculty, staff), from each participating university.

The following table summarizes the universities contacted and their responses:

University Response		University Response		University	Response	
Harvard	Data Received	Princeton	Data Received	MIT	Data Received	
Brown	No Response	Cornell	Unusable Data	UPenn	Unusable Data	
Dartmouth	No Response	Columbia	Unusable Data	Stanford	No Response	
UChicago	Unusable Data	Duke	Insufficient Time	Johns Hopkins	No Response	
Northwestern	No Response	WUSTL	No Response	NYU	Unusable Data	

 Table 3: University Contacts for Outside Data

After learning about the NYS Collaborative, we excluded New York schools from the data collection process, as their flu vaccine efforts were sure to change over the study period. UChicago and UPenn UHS had fragmented vaccination frameworks and were not able to provide the data requested. Duke was contacted late in the season, and they were not able to fulfill the request within the time constraints of the project.

4.2 Results

Data was received from a total of four universities: Yale, Harvard, Princeton, and MIT (see Appendix for raw data). Due to limitations of electronic medical records and data gathering, UHS found it difficult to accurately tabulate or estimate some of the data points. Of particular concern was the inability to distinguish between undergraduate and graduate students or faculty and staff in some cases, because vaccinations were coded as student or employee. Due to this limitation, the finest distinction the analysis uses is students vs. employees. It was also sometimes difficult for UHS to estimate the eligible count or denominator in the uptake rate fraction, particularly of faculty and staff. This is because often dependents, spouses, and/or retirees are eligible to receive the vaccine, and it was nigh impossible to estimate how many individuals composed those categories. Later, we discovered that all four universities had Offices of Institutional Research (OIR) which keep publicly available statistics and participate in the Common Data Set (CDS) Initiative, which provides consistent definitions of a variety of university statistics for cross-university comparisons. We therefore used OIR data for eligible counts to the fullest extent possible (see Appendix for exact methodology).

The following table shows flu vaccine uptake rates, calculated as number of vaccines given divided by total eligible, stratified by students vs. employees:

University	Year	Student Uptake	Employee Uptake	
	2014	0.31	0.62	
Yale	2015	0.30	0.61	
	2016	0.31	0.62	
	2014	0.18	0.65	
Harvard	2015	0.22	0.54	
	2016	0.26	0.40	
	2014	0.38	0.40	
Princeton	2015	0.38	0.37	
	2016	0.36	0.37	
	2014	0.30	0.89	
MIT	2015	0.40	0.75	
	2016	0.48	0.68	

 Table 4: Calculated Uptake Rates

It is important to note that we should not interpret nominal employee uptake rates because of the previously mentioned difficulty of different universities having different eligible populations. The denominators used include only faculty and staff, but the numerators can include dependents spouses, and/or retirees, depending on institutional policy. Because students are a much better defined category, we can directly interpret the student uptake column as long as the positive effect of student dependents and the negative effect of not counting flu vaccines obtained outside of UHS are small. Since the vast majority of students do not have children, and all four institutions offer the vaccine free to students (see Table 6), this assumption seems reasonable. Vaccine uptake among students at these four institutions for the years 2014-16 averages around 30%, with a range of 18%-48%, which is consistent with the previously cited University of Minnesota, St. Paul study.

Before running a formal regression, it is prudent to first graph the trends in uptake rates through time to visually confirm a possible intervention effect. We focus on two main specifications: considering each university's overall uptake rate as a whole, and focusing only on student uptake rates, with the logic that the intervention affected mostly students.



Figure 7: Total Uptake Rate Trends Figure 8: Student Uptake Rate Trends

Yale's total uptake rate did not change appreciably from 2014 and 2015 to 2016, but the total uptake rates of the other universities trended downwards overall, so there may be a positive DiD quantity to estimate. Focusing on students, Yale's uptake rate again did not change appreciably over the three years, but two out of three control institutions trended upwards, making it unlikely that the DiD estimate is positive.

We now compute formal estimates with the following DiD regression model:

$$uptake_{it} = \beta_0 + \beta_1 1 \{ Yale, 2016 \} + \gamma_i + \eta_t + \epsilon_{it}$$
(1)

where γ_i and η_t are university and year fixed effects, respectively. We use as a baseline specification total uptake rates (indexed by 1) and two years of data, 2015 and 2016 (indexed by 0.1). We also consider student uptake rates as the dependent variable (indexed by 2), and given that MIT's student uptake trend appears to be an outlier, possibly signaling incremental changes to flu vaccine publicity that would violate the assumption of our model, we consider student uptake rates without MIT (indexed by 3). Finally, we try the three main specifications with all available data by adding 2014 (indexed by 0.2), for a total of six specifications:

- 1.1 Total Uptake Rates, 2015 and 2016 only
- 1.2 Total Uptake Rates + 2014
- 2.1 Student Uptake Rates, 2015 and 2016 only
- 2.2 Student Uptake Rates + 2014
- 3.1 Student Uptake Rates MIT, 2015 and 2016 only
- 3.2 Student Uptake Rates MIT + 2014

	Table 9.		regression	ricebuild		
	(1.1)	(1.2)	(2.1)	(2.2)	(3.1)	(3.2)
	b/se	b/ <i>s</i> e	b/ <i>s</i> e	b/ <i>s</i> e	b/se	b/se
treated	0_03	0.03	-0.03	-0.05	-0.00	-0_02
	(0.02)	(0.02)	(0.05)	(0.06)	(0.06)	(0.06)

Table 5	: Main	DiD	Regression	Results
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Standard errors clustered by university are in parentheses.

None of the specifications yielded a significantly positive estimate of the effect of the intervention. In fact, the student-only estimates are wrong-signed, even after removing the outlier MIT.

5 University Policies

5.1 Methods

Universities vary widely in flu vaccine policy - how the vaccine is offered, charged for, and publicized. Information was initially collected from UHS websites to the extent possible. Some administrators who responded to the data requests also completed short interviews about flu vaccine policy at their schools. These include the UHS of Harvard, Princeton, and MIT.

5.2 Results

UHS post information about their flu vaccine policies in varying degrees of detail, on their websites. The following table summarizes characteristics of various UHS flu vaccination programs, based on publicly available information:

University	Free (Students)	Free (Faculty/Staff)	Walk-in Hours	Flu Clinics
Yale	Yes	Yes	Yes	Yes
Harvard	Yes	Yes	Yes	Yes
Princeton	Yes	Yes	No	Yes
MIT	Yes	Yes	Yes	Yes
Brown	Yes	Yes	No	Yes
Cornell	Yes	Yes	Yes	Yes
UPenn	No	Yes	No	Yes
Dartmouth	?	?	No	?
Columbia	Yes	Yes	Yes	No
Stanford	Yes	Yes	Yes	Yes
UChicago	Yes	Yes	?	Yes
Duke	Yes	Yes	No	?
Johns Hopkins	No	?	No	Yes
Northwestern	No	No	No	No
WUSTL	?	?	No	No
NYU	Yes	No	No	Yes

 Table 6: Flu Vaccine Policy Characteristics

A question mark denotes missing or unclear information. The "Free" columns denote a "Free with ID" or no upfront payment required policy, regardless of insurance status.⁴ The "Walk-in Hours" column denotes UHS that offer immunizations without appointments at certain hours, while the "Flu Clinics" column denotes UHS that set up walk-in, fast-turnaround clinics specifically for administering the flu vaccine.

⁴This is a meaningful distinction to make despite the provisions of the ACA which guarantee the vaccine to be effectively free to all insured individuals because, in a free vaccine policy, the university is the payer, signaling institutional investment into preventive care.

Taken together, these characteristics give a sense of the cost of and access to the flu vaccine at these universities. While most have free vaccine policies and offer flu clinics, several universities do not offer one or more policies, and there is a fair amount of variability in policy.

In a somewhat surprising discovery, many important aspects of university policy, revealed in personal interviews with UHS administration, could not be gleaned from the information summarized in the above table. What follows are several case-study style narratives that we believe illustrate the extensive differences in factors like institutional support and publicity efforts that exist between universities.

Yale

Yale Health offers a free flu vaccine to anyone with a Yale ID as well as dependents, spouses, and retirees. Individuals can make an appointment at any time or participate in weekly immunization walk-in hours at the Yale Health Center. Yale Health providers also recommend the vaccine to patients during routine care. In addition, the UHS organizes a series of about ten flu clinics throughout the months of October - December, most at the Yale Health Center but a few in other campus locations, where walk-ins can receive the flu vaccine in less than ten minutes. Despite the substantial monetary investment that makes the free vaccines and clinics possible, Yale Health does little to publicize their availability. Each year, a single email is sent at the end of September that links to the flu clinic schedule. It makes no mention of walk-in hours, nor is there any further reminder of the clinics, most of which are over a month away at the time of sending.

Princeton

Immunizations became a priority for the Princeton administration after the 2013 meningitis B outbreak. Princeton Health Services adopted an electronic medical record (EMR) tailored for colleges called Medicat, which they use to track immunization compliance for all their students. In particular, students with chronic conditions or other risk factors are specifically messaged to encourage receipt of the flu vaccine. Publicity starts early and is a collaboration between the health promotion arm of UHS and the student advisory board; efforts include tables at dining halls and poster campaigns on campus. Ordinarily immunizations require appointments and incur a charge, but each year the university funds a heavily publicized 2-3 day event called FluFest, which offers the flu vaccine free with Princeton ID and administers the majority of vaccines each season.

Harvard

Harvard Health Services, like Yale Health, offers the flu vaccine free to the entire Harvard community. Flu clinics at UHS begin in September and continue, twice a week, through the entire fall semester. In order to service the entire campus, professional schools hold their own clinics, and in order to target undergraduates, some clinics are even held in dining halls. Starting in 2013, Harvard Health Services began working with an undergraduate student group to promote health and preventive care. Publicity for the flu vaccine is extensive and

includes advertising on the internal website, tabling in residence halls, poster campaigns, and student outreach.

6 Discussion

6.1 Results

Limitations

We first acknowledge the limitations of this work. Because this project was conducted independently of Yale Health and university administration (other than the uptake data provided by the former), it naturally lacked the scope, personnel, and funding that would be ideal. Without access to university-wide email and messaging systems, it was impossible to obtain representative survey data and difficult to reach faculty and staff, so we could not meaningfully interpret the raw proportions of survey responses. Without institutional or financial support, we could not send messages as university entities; print posters that were colored, large in size, or large in number; boost social media posts; or offer compensation or prize drawings for the survey or the decision to obtain the vaccine.

There were also independent limitations of data collection. Most of the universities contacted for data were emailed several times to different administrators, but the non-response rate was high. Aside from making contact, the problem of how to determine the exact flu vaccine uptake rate on a college campus based on a consistent definition was a surprisingly difficult one. UHS generally do not have data on members of a college community who receive the vaccine at local pharmacies or external providers, and we have made the assumption in this paper that, for the four universities studied, those numbers are small and approximately equal in proportion between universities. Differing EMR and health system setups may also not differentiate between dependents, spouses, and retirees; undergraduate and graduate students; or faculty and staff. The ways that university OIR count community members by affiliation can also differ from each other and from the desired count definitions of members eligible for the flu vaccine. Because of these difficulties, as with the survey data, we have been careful in this paper how we interpret our uptake data.

Observations

Given the aforementioned limitations, it is unsurprising that we were unable to measure a statistically significant effect of the intervention on uptake. Only about a quarter of the flu clinics were publicized, and compared to the size of an entire student body, the scale of the promotion was very small. Our study was also underpowered due to the small size of the data set.

However, this work has still identified several contributions to the literature:

• We have provided some novel rough estimates of flu vaccine uptake among college students to add to the limited extant data, which is largely survey-based. These estimates corroborate the consensus that college students are undervaccinated.

- We have shown that there are nontrivial misconceptions about the safety and efficacy of the vaccine in this subpopulation. While it is hard to tell how the prevalence of misconception compares to society as a whole, it is definitively not the case that institutions of higher learning are immune to confusion about the science of vaccines.
- We have collated and compared flu vaccine policy for a sample of universities.
 - University students and employees experience widely varying levels of access to the flu vaccine depending on the institution to which they are part. They may be charged for their own, their spouse's, or their childrens' vaccines. They may have to specially make appointments to an out-of-the-way health center to be vaccinated. Or they may be able to bring their entire family to a conveniently located flu clinic and walk in and out through a fast-moving line - and every scenario in between. The exact decision a potential recipient of the vaccine faces depends directly on the level of their institution's investment, both human and monetary, into the vaccine.
 - Even universities whose policies look similar on paper can have important differences in institutional support. For example, Yale invests heavily in a free vaccine for the entire university community but lacks promotional efforts to encourage vaccine uptake. At Princeton and Harvard, through separate paths, immunizing the community became a priority of university leadership, and accordingly both UHS and students are involved in heavy publicity and reminders to obtain the flu vaccine. However, Princeton flu vaccines are only free at FluFest, and dependents are not covered, while Harvard has the same universal policy as Yale.

6.2 Recommendations

Based on results and lessons learned from this project, we offer a few recommendations for researchers and college health administrators towards the goal of improving flu vaccine uptake at their universities:

- Seek administration sponsorship for preventive care efforts. Support from university leadership is crucial for goals such as representative attitude surveys, which would be critical additions to the literature, and increases in funding for free vaccine policies and expanded flu clinics.
- Set goals to expand publicity efforts and improve process measures. Returning to the motivating model, obtaining vaccines is an all-or-nothing decision, and while the marginal effect of a single change or initiative may be small, cumulative improvements will push people over their thresholds, and uptake will increase.
- Keep as detailed vaccination records as possible. The more information that is known about uptake trends and covariates, the greater the research productivity in this small field, and the more evidence-based interventions and improvements will be discovered. One could imagine that, with more data, we could begin teasing out how aspects of policy are associated with and affect uptake.

• Coordinate and collaborate with peers in other institutions. Collaboration will aid in all aspects of this process. Common survey and data definitions would facilitate valid cross-campus comparisons, and undertaking efforts simultaneously both motivates individual efforts and encourages reciprocal learning.

7 Conclusion

In this paper, we reviewed the economics of vaccines and advanced a cost-benefit framework to model efforts to increase flu vaccine uptake. We then executed a small-scale research design, the limited but tangible results of which serve as proof of concept of the potential value of research and intervention in this area at scale. Universities can generate valuable knowledge and significantly advance health in their communities through institutionally sponsored endeavors and willing collaboration.

Perhaps the best argument for supporting preventive care at the college level comes from a classic model in health economics, the Grossman Model of the Demand for Health [16]. The key insight of this model is that health is both an investment and a consumption good - that is, greater health not only increases the number of healthy days a person can use for work or leisure, but also directly feels better than worse health.

An implication of the investment nature of health is that an expansion of flu vaccine access or promotion would not be an unmitigated cost. Staff may take fewer sick days, faculty may experience greater research productivity, and students may produce better academic work. An implication of the consumption nature of health is that decreased incidence of flu, independent of productivity effects, would increase the overall personal welfare of the university community.

One metric by which researchers evaluate preventive care for healthcare systems is whether or not it is cost saving, meaning the money saved from not treating those who do not get sick exceeds the money spent on the preventive care. There is not a consensus in the literature about whether preventive care is cost saving or simply a cost effective medical treatment - and of course, this varies depending on the type of preventive care. But we argue that, in the college setting, this distinction does not matter. Cost saving for its UHS or not, any university concerned with a strong academic focus and the wellbeing of its community would do well by its central mission to research and invest in preventive care. And within this context, bridging the influenza herd immunity gap is a particularly worthy goal.

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university	year	u_vax	u_total	g_vax	g_total	f_vax	f_total	s_vax	s_total
Yale	2014	1696	5477	2123	6859	1038	1687	5755	9357
Yale	2015	1683	5532	2084	6853	992	1635	5737	9455
Yale	2016	1682	5472	2148	6986	1011	1635	5906	9548
Harvard	2014	1712	6644	2131	14192	1573	2012	9917	15608
Harvard	2015	1834	6648	2826	14192	1293	2012	8156	15608
Harvard	2016	2247	6646	3224	14192	959	2012	6048	15608
Princeton	2014	2159	5275	887	2697	490	1103	2168	5562
Princeton	2015	2164	5277	920	2736	477	1172	2000	5562
Princeton	2016	2069	5251	836	2781	450	1172	2034	5562
MIT	2014	1179	4512	2252	6807	966	1504	10016	10822
MIT	2015	1667	4527	2879	6804	934	1544	8588	11073
MIT	2016	2199	4524	3211	6852	1017	1544	7780	11372

Appendix: Raw Vaccine Data

Prefixes stand for undergraduate, graduate, faculty, and staff. Vaccination data was obtained from UHS data requests. Total numbers were obtained from university Offices of Institutional Research (OIR) websites. Many OIR participate in the Common Data Set (CDS) Initiative; undergraduate, graduate, and faculty counts were obtained from CDS files when possible, as they are guaranteed to have consistent definitions. When CDS data was not available, OIR data tables were used. Since staff count is not an item in the CDS, OIR data tables were exclusively used for staff. When no data was available, the previous year's value was used as a substitute, indicated by green shading. Orange shading in the vaccination columns indicates cells for which only data for students or employees was available; the totals were apportioned to equalize the uptake rates in the two subcategories (either undergraduate and graduate or faculty and staff).