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Some State Vaccination Laws Contribute To Greater Exemption Rates And Disease Outbreaks In The United States

ABSTRACT Health officials attest that immunizations are among the most successful interventions in public health. However, there remains a substantial unvaccinated population in the United States. We analyzed how state-level vaccination exemption laws affect immunization rates and the incidence of preventable disease. We measured the association between each component of state kindergarten vaccination exemption laws and state vaccination exemption rates from 2002 to 2012, using the Centers for Disease Control and Prevention's annual school assessment reports. We found that policies such as requiring health department approval of nonmedical exemptions, requiring a physician to sign an exemption application, and having criminal or civil punishments for noncompliance with immunization requirements had a significant effect in reducing vaccine exemptions. Our exemption law effectiveness index identified eighteen states with the most effective laws and nine states with the least effective ones. The most effective states had lower incidences of pertussis, compared to other states. For policy makers interested in decreasing the number of vaccine exemptions in their state, our findings are of particular interest.

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In recent years preventable diseases such as pertussis (whooping cough), measles, and mumps have been on the rise. Measles had largely been eliminated in the United States by 2000, but lately there has been a resurgence. On January 13, 2015, health officials warned that a Disneyland visitor was linked to at least seven cases of measles in California and two cases in Utah; six of those patients had not been vaccinated. By March 2015, California had 133 confirmed measles cases, and four other states had cases linking back to the Disneyland visitor. Among the measles patients in California for whom vaccination documentation was available, 57 were unvaccinated.[1] Because vaccines rely in part on herd immunity for their effectiveness, this surge in disease has been popularly attributed to falling vaccination rates, particularly within local clusters such as those involved in the spread of measles in California from the infected Disneyland visitor.[1,2]

The United States does not have a national vaccination requirement. One way state policy makers incentivize people to vaccinate their children is through the educational system. Before a child can enter kindergarten in any state, she or he must either be vaccinated or have a vaccination exemption. In most states, kindergarten vaccination exemptions can be granted for medical reasons (the child has some physical ailment that prevents vaccination), religious reasons (vaccinations violate the parents' religious beliefs), or philosophical reasons (for example, vaccinations are not in accordance with the parents' philosophical beliefs).

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Vaccination exemption rates vary significantly across the United States. In 2012 exemption rates ranged from a low of approximately 0.45 percent in New Mexico to a high of 6.5 percent in Oregon (see online Appendix 1).[3]

If an increasing number of parents do not vaccinate their children and instead opt for an exemption, the United States could experience a general increase in preventable disease.[4,5] If this association holds, state public health officials may want to advocate reconsidering state laws and policies that ease the exemption process, to avoid unnecessary illness. Note that the rules governing when a child must be vaccinated may be included in laws, policies, or both.

Numerous studies have examined vaccination exemption policy.[4,6–11] However, few studies have been conducted that simultaneously and dynamically assess the impact of the multiple components of exemption policy on exemption rates.[12]

Our study extends this literature in three ways. First, we used a comprehensive vaccine law database that tracked over a dozen separate components of state laws over time, which made a longitudinal analysis possible. Second, we estimated a policy effectiveness model that evaluated the impact of each type of law on exemption rates, and we used that model to construct an index of exemption law effectiveness that weighted each policy component by its contribution to overall exemption rates. This index supported a summary index measure of which states had the most effective portfolio of vaccine policies. Third, we present evidence that states with more effective portfolios (states with higher values on our summary index) also had lower rates of pertussis.

Vaccination exemption rates have drastically increased in the past ten years, with almost all of the increase coming from nonmedical—that is, religious and philosophical—exemptions. The increase in nonmedical exemptions suggests that the public's perceptions of vaccines have changed in the past decade, partly because of concerns about vaccine safety. For example, despite numerous reports showing no link between the measles-mumps-rubella (MMR) vaccine and autism, pockets of doubt remain among the public regarding the safety of that vaccine. In addition to the safety of vaccines, some parents also question their effectiveness.[13,14]

State policies may also be contributing to the observed increase in exemption rates. Every state has different exemption regulations as well as different language to describe and implement them. Some states have strict requirements, including that the state department of health approve all exemptions; other states have almost no restrictions, and parents can essentially check a box on a form and send their child unvaccinated to school.[9,13]

For states with laws and policies that make exemptions particularly easy to obtain, the time cost of vaccinating one's child might be greater than that of filing an exemption. This is particularly true for parents who register their children for school at the last minute. If a child is still unvaccinated on the first day of kindergarten or first grade, it may be logistically impossible to vaccinate the child before the start of school. In such cases, filling out an exemption form at school might be the quickest and easiest option. Similarly, for parents who would incur high time costs if they took their child to a clinic to be vaccinated because of work constraints, lack of transportation, and so forth, filling out an exemption might be a lower-cost option.[5]

State exemption laws vary in stringency and purpose (Exhibit 1). For example, the use of a standardized exemption application form is likely not meant to hinder exceptions but instead to make the application process more uniform and efficient. In contrast, some states impose a criminal or civil punishment on the child (such as expulsion from school) or parent (such as filing criminal charges of negligence) for failure to comply with vaccination regulations. Thus, not all components of vaccine exemption policies are equal, nor would they be expected to have the same impact on exemption rates.

This study measured the extent to which each of these components of state-level exemption policy was associated with a higher or lower number of applications for vaccine exemptions filed in each state and year. From these estimated associations, we created a state-level summary index that ranked states by the effectiveness of their vaccination exemption laws. Finally, we looked at the association of that effectiveness and preventable disease outbreaks.

Study Data And Methods

The kindergarten vaccination exemption data used in this study came from the Centers for Disease Control and Prevention's 2002–12 annual school assessment reports.[15] These state-based surveys are the primary source of information on vaccination coverage of children in the United States and one of the few sources of exemption data available.

However, these data are not perfect, because they are based on survey data from each state. As a result of this sampling method, some of the drawbacks of the data are that some states sample only selected students instead of the entire student population; the data are generally collected at the beginning of the school year, when

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EXHIBIT 1

Components Of Vaccination Exemption Policies And Number Of States With Each Component In 2012

Component	Explanation	No. of states
Provisional admission to school	Partially vaccinated children or children who are missing immunization records may be admitted to school for a set period of time until records can be submitted or vaccinations brought up to date.	44
Use of standardized state exemption application forms	There are standardized exemption application forms.	39
Notarization of exemption	Exemption forms must be notarized prior to submission.	14
Scalable request for exemption from only particular vaccines	Some states require that an exemption from vaccination, especially a nonmedical exemption, must be requested for all required vaccines. Scalable requests permit the parent or other adult to indicate for which vaccine(s) exemption is being requested.	17
Submission of written statement requesting nonmedical exemption	Parents must submit a written statement requesting a religious or philosophical exemption.	46
Requirements for department of health or school to review, sign, or approve nonmedical exemption forms	This law is related to exemption from vaccination based on religion or philosophy or conscientious belief, which requires the department of health at either the local or state level to review exemption applications or forms and decide whether to approve and sign off on the applications.	4
Requirements for department of health to review and approve medical exemption forms	This law is related to exemption from vaccination based on medical concerns that require the department of health at either the local or state level to review exemption applications or forms and decide whether to approve and sign off on the applications.	3
Submission of written statement from a professional supporting request for religious exemption	A member of the clergy or other religious leader must submit a written statement to support the parent's written statement indicating that vaccination conflicts with his or her religion.	6
Nonphysicians cannot sign exemption forms	Only physicians (MDs or DOs) can sign exemption forms.	20
Nonphysicians can sign exemption forms	Nonphysicians such as physician assistants and nurse practitioners can sign exemption forms.	22
Criminal, civil, or both penalties related to vaccination exemption	Criminal, civil, or both penalties are associated with various aspects of refusing vaccinations, including loss of state benefits or eligibility for them.	16
Annual renewal	Vaccine exemption forms must be submitted annually.	9
Philosophical exemption available	Parents must submit a written statement requesting an exemption based on personal, moral, or other belief.	17

SOURCE Authors' analysis of data from state department of health websites and 2011 data from the State Vaccination Requirements and Exemption Law Database (Note 17 in text). **NOTE** For the purpose of this analysis, the District of Columbia is considered to be a state.

vaccination rates may be lower than they would be later in the school year; and some states have missing years of data. Additionally, since the data are voluntarily reported by the state, response bias is possible if states with either particularly good or particularly bad vaccination rates have different incentives in reporting exemptions. To address these possible concerns, we ran a series of robustness checks on our model to verify that any noise in the data was not affecting our conclusions.

We included in our model a set of state-level time-varying characteristics from the Area Health Resources Files.[16] These files collect data from over fifty sources, including the American Hospital Association, Bureau of Labor Statistics, and National Center for Health Statistics. The files are maintained by the Health Resources and Services Administration and contain data on many county-level health and population characteristics.

We included measures of annual state-level socioeconomic characteristics and economic conditions that could be associated with obtaining an exemption. Some of the measures were the percentage of the population that was white, the percentage of births that were very low birthweight, the percentage of the population with a bachelor's degree or higher level of education, the poverty rate, and the unemployment rate.

State-specific data on vaccine exemption laws for 2011 were obtained from the State Vaccination Requirements and Exemption Law Database.[17] This is the most complete and comprehensive legal database available on vaccination requirements, and it includes 2,000 current statutes and regulations from the fifty states and the District of Columbia.

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Because of the volume of regulations and inconsistent policy language across states, trying to compare policies across states and over time was not a simple task. We extracted our variables from this database by reviewing each state's vaccine laws and any changes over time. We then verified information from the database against the current information about vaccination exemption procedures on the website of each state's department of health.

This method of data collection differs from previous work by Nina Blank and coauthors, who identified state-level vaccine laws by interviewing immunization program officials at the state level at a single point in time.[12] In contrast, our vaccine measurements were an abstraction by legal scholars of actual regulatory language, and we could identify changes in laws over time.[7,12,17] Indicator variables for each policy were included in our model of policy effectiveness.

LAW EFFECTIVENESS INDEX To measure the effectiveness of each component of each law in reducing vaccine exemptions, we explored three regression analysis specifications that are designed for longitudinal data such as ours. We specified our final model using a random-effects estimator, a population average estimator, and a simple linear regression model with clustered standard errors (at the state level) for the period 2002–12.[18] The results were consistent across all three specifications, and our ultimate index of effectiveness was robust to model selection.

For expositional purposes, we present the results from the random-effects model, but the full set of results is available upon request from the authors. Using the random-effects model specification allowed us to statistically control for year effects and unobserved state heterogeneity. Ultimately, this made it possible for us to parse out the marginal effect of each policy component on exemption rates.[19]

Not all laws are equally effective in making vaccination exemptions more difficult to obtain. Thus, it did not seem intuitive to create an index that weighted each law component equally, although this is the approach taken in much of the existing literature.[4,8,10,12,20] It would be preferable to rank states based on their total ability to reduce exemptions, instead of using a ranking that reflected the number of laws in each state. Using the significant regression coefficients as weights for such an index was a systematic way to combine the policies into a single summary statistic, which was preferable to the common practice of just summing the number of policy components a state had. Thus, in our ranking system, if one state had four relatively ineffective policies and another state had one very effective policy, the state with the single effective policy had a higher rank than the other state.

We found a link between our index of exemption law effectiveness and the incidence of preventable diseases.

Our index was therefore constructed by summing the significant policy coefficients (from our exemption regression) multiplied by the corresponding indicator variables for whether the state had each policy component. (Excluding policies that were not significant is equivalent to giving them a weight of 0 in the index.) We then grouped the index numbers into four categories—most effective, moderately effective, less effective, and least effective—that corresponded to the quartiles of our index.

POLICY EFFECTIVENESS ESTIMATION The dependent variable in our regression analysis was the total (medical, religious, and philosophical) state exemption rates. To see why we included all exemptions and not just nonmedical ones, consider the case of Washington State.

In 2009 Washington had a change in policy that required parents or guardians of children to get a doctor's signature to obtain a vaccination exemption. This successfully reduced the annual number of nonmedical exemptions by 30 percent by 2012. However, it appears to have had an offsetting effect on medical exemptions, which increased by 253 percent (from 309 in 2009 to 1,092 to 2012). This suggests that the change in policy could have incentivized some people to obtain medical exemptions who previously would have been more likely to obtain nonmedical exemptions. To account for this and other possible substitution behavior, we looked at policy effects on total vaccination exemptions.

In presenting the associations between each law component and the vaccine exemption rate, we highlight the results from our random-effects regression analysis covering the period 2002–10. Again, the dependent variable was the state's exemption rate (the percentage of kindergarteners with an exemption). The independent variables were each policy component listed in Exhibit 1, the state characteristics discussed above, and year indicator variables.

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The coefficients and standard errors from the random-effects model are discussed below; alternative models are not discussed in detail. As a robustness check, we ran a version of the model that excluded states with very low response rates (less than 10 percent) to the annual school assessment reports. Excluding such states did not affect the results.

Study Results

Eighteen states were found to have the most effective vaccination exemption policies, while nine states had the least effective policies, according to our index (Exhibit 2). The index for all states and the District of Columbia for each year from 2002 to 2012 is available from the authors upon request. Mississippi and West Virginia received no index ranking because they do not permit any nonmedical exemptions (which makes the predicted value of the index 0).

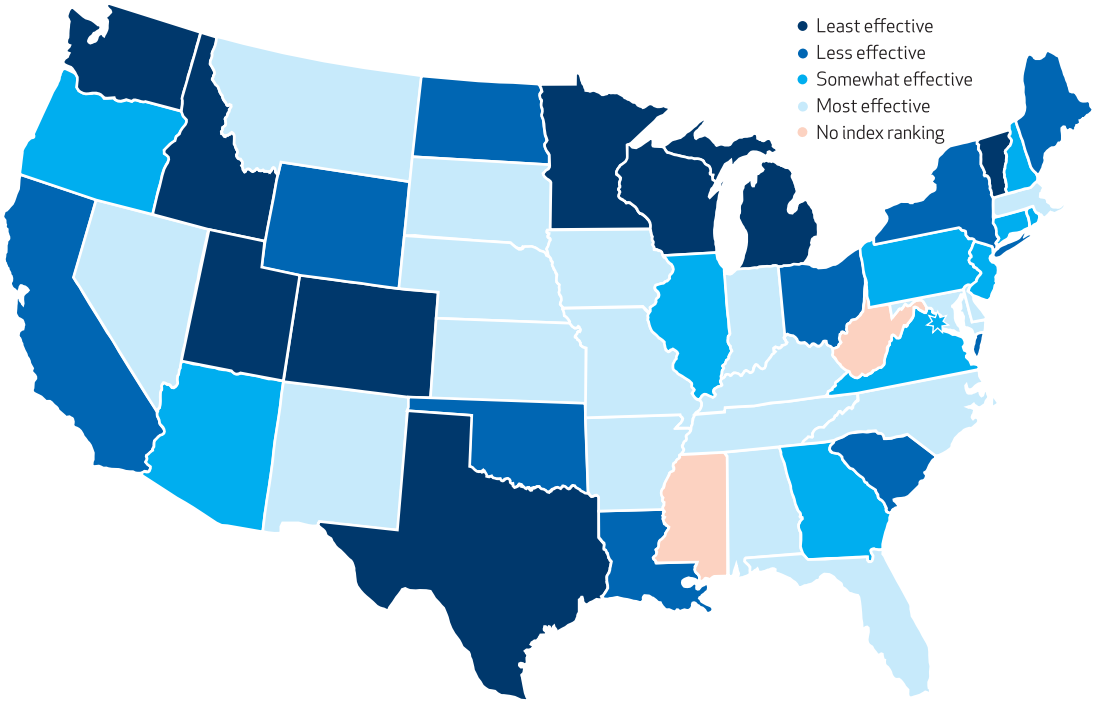
POLICIES THAT LOWER EXEMPTION RATES We found that requiring a state health department to approve applications for a nonmedical vaccination exemption had a significant association with lowering exemption rates: States with that requirement had rates 1.12 percent lower, compared to states without the requirement (Exhibit 3). Presumably, this is one of the most difficult obstacles to overcome in obtaining an exemption, given a health department's interest in preserving herd immunity within the state.

Consistent with previous research,[6–9,12] we found that states that allowed philosophical exemptions had exemption rates 0.1 percent higher than states that did not allow those exemptions (Exhibit 3). Many states required proof of immunity for medical exemptions and a written statement from a professional verifying a religious conflict with vaccination (the religious sincerity component) for religious exemptions. Therefore, philosophical exemptions have the potential to be easier or less costly to acquire than, for example, a medical exemption.

Another component associated with lower exemption rates was the ability to be exempt from

EXHIBIT 2

States By Quartile Of Exemption Law Effectiveness Index, 2012



SOURCE Authors' analysis of data from the following sources: (1) the 2002–12 Centers for Disease Control and Prevention's annual school assessment reports (Note 15 in text); (2) 2011 data from the State Vaccination Requirements and Exemption Law Database (Note 17 in text); and (3) 2012–13 data from the Area Health Resources File (Note 16 in text). **NOTES** "Most effective" states are those in the highest quartile of our exemption law effectiveness index; "least effective" states are those in the lowest quartile. Mississippi and West Virginia do not permit nonmedical exemptions from vaccination requirements. Thus, their scores on the index—which assesses the effectiveness of both nonmedical and medical exemption policies—would not be accurate, and they are not included in any of the four quartiles. Alaska and Hawaii are excluded from the map for ease of presentation, although they were included in the quartiles.

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EXHIBIT 3

Effects Of Components Of Vaccination Exemption Polices On Exemption Rates, 2002–12

Policy component	Random effect	Population average
Provisional admission	−0.001	−0.0009
Standard form	0.0103***	0.0103***
Notarization	−0.003	−0.0028
Scalable request	−0.007**	−0.007**
Written statement	0.005	0.0049
Health department must approve medical application	−0.001	−0.0003
Health department must approve nonmedical applications	−0.0112*	−0.0113*
Religious sincerity	−0.002	−0.002
Nonphysician cannot sign	−0.005*	−0.0048*
Nonphysician can sign	−0.002	−0.0019
Criminal or civil penalties	−0.006***	−0.0063***
Annual renewal	−0.003	−0.0028
Philosophical exemption	0.001***	0.0095***

SOURCE Authors' analysis of the following: (1) 2002–12 data from the Centers for Disease Control and Prevention's annual school assessment reports (Note 15 in text); (2) 2011 data from the State Vaccination Requirements and Exemption Law Database (Note 17 in text); and (3) 2012–13 data from the Area Health Resources File (Note 16 in text). **NOTES** Results are based on regression analysis. The dependent variable is the percentage of kindergarteners with an exemption in a given state. State characteristics and year effects were included in all models. There were 468 observations. An unabridged version of this table is available in the Appendix (Note 3 in text). $^{*}p < 0.10$ $^{**}p < 0.05$ $^{***}p < 0.01$

only specific vaccines instead of all vaccines (the scalable request component). This reduced exemption rates by 0.7 percent (Exhibit 3). In addition, criminal and civil punishment reduced exemption rates by 0.6 percent.

Within the past few years, numerous states have made administrative changes to their vaccination exemption laws and have adopted a standardized exemption form. Such policies are important for clerical accuracy and tracking. However, we found that they did not lower exemption rates but instead were associated with a 1.0 percent increase in the rates (Exhibit 3).

These results suggest that not all policies are created equal. Some states have numerous laws related to exemption rates. But if these laws are not effectively reducing nonmedical exemption rates, then more is not necessarily better or more effective.

POLICY EFFECTIVENESS AND PREVENTABLE DISEASE OUTBREAKS Our exemption law effectiveness index allowed us to examine whether states with more effective laws also had fewer cases of preventable diseases. We measured the incidence of pertussis per 100,000 people since there is a wide range in state population sizes.

We did not find a perfectly linear relationship between the index ranking and disease incidence. Instead, we found a general trend: Least and less effective states had higher average preventable disease rates per 100,000 people, compared to most and moderately effective states (Exhibit 4).[11] When we compared pertussis incidence during 2002–12, the most effective states had an average incidence of 7.30 cases, in contrast to 16.06 cases in the least effective states. This difference was even more pronounced when we looked just at 2012: 16.45 cases versus 54.19 cases, respectively.

To test the validity of this perceived trend, we conducted a series of *t*-tests on the null hypothesis that the average pertussis incidence was the same across states with different policy effectiveness, as measured by our index for 2012. When we compared the least effective states to all other states, we found 38.67 fewer cases of pertussis per 100,000 people in states in the top three quartiles (data not shown; $p < 0.01$). As noted above, the most effective states had 37.74 fewer cases of pertussis than the least effective states

EXHIBIT 4

Average Number Of Cases Of Pertussis Per 100,000 People, By Quartile Of Exemption Law Effectiveness Index

	2002–12	2012
Most effective states	7.30	16.45
Moderately effective states	6.07	11.97
Less effective states	7.53	18.14
Least effective states	16.06	54.19
National average	8.43	22.63

SOURCE Authors' analysis of data from the following: (1) the 2002–12 Centers for Disease Control and Prevention's annual school assessment reports (Note 15 in text); (2) 2011 data from the State Vaccination Requirements and Exemption Law Database (Note 17 in text); and (3) 2012–13 data from the Area Health Resources File (Note 16 in text). **NOTES** There were 539 observations in 2002–12 and 49 in 2012 alone. "Most effective states" are those in the highest quartile of our law effectiveness index; "least effective states" are those in the lowest quartile.

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Vaccine exemption policy is an important part of a comprehensive plan for reducing preventable diseases.

(Exhibit 4).

We also measured the association of pertussis incidence and state exemption law effectiveness using a random-effects regression model with state characteristic variables and year dummies. Again, we found a significant relationship between effectiveness of exemption laws and pertussis incidence. The most effective states had 7.02 fewer cases ($p < 0.01$) of pertussis per 100,000 people, compared to the least effective states (see the Appendix).[3] Moderately effective states and less effective states had 6.55 fewer and 5.66 fewer (both $p < 0.01$) cases of pertussis per 100,000 people, respectively, compared to the least effective states. These results suggest a significant association between increased pertussis incidence and less effective vaccination exemption policy at the state level.

Conclusion

The goal of this research was to illuminate the relationship between various types of vaccination policies and state-level vaccination exemption rates, to aid policy makers and public health planners in targeting specific policy interventions intended to decrease the number of exemptions given and ultimately reduce the incidence of preventable diseases. Our findings suggest that not all laws related to vaccination exemptions have the same impact on exemption rates. For example, a state's adoption of a standard exemption form might be useful for administrative purposes, but that adoption was associated with increased rates of vaccine exemptions. This is particularly important since these administrative changes are the most popular recent policy reforms.

However, we did find that other policies—such as requiring that the state department of health approve nonmedical exemptions, requiring that a physician sign an exemption application, and having criminal or civil punishments for noncompliance with vaccination requirements—had a significant effect in reducing exemption rates. Such policies could be of particular interest to policy makers interested in decreasing the exemption rate in their state.

Finally, we also found a link between our index of exemption law effectiveness and the incidence of preventable diseases. States that had the most effective portfolio of policies had lower incidences of pertussis. Vaccine exemption policy is thus an important part of a comprehensive plan for reducing preventable diseases. States have tools available to optimize their policies, if public health officials wish to decrease exemptions and disease outbreaks. Indeed, Gov. Jerry Brown of California recently signed legislation that strengthened that state's vaccination exemption law,[21] putting it alongside Mississippi and West Virginia as states that allow exemptions for medical reasons only. As vaccination exemption rates fall well below the levels required for herd immunity in many areas, our findings suggest that states with weaker overall exemption standards may wish to reconsider those vaccine laws and policies. ■

NOTES

1 California Department of Public Health. California measles surveillance update [Internet]. Sacramento (CA): CDPH; 2015 Mar 13 [cited 2015 Jun 4]. Available from: http://www.cdph.ca.gov/programs/immunize/Documents/Measles_update_3_-_13_-_2015_public.pdf

2 Disease outbreak is not a simple issue, and there may be confounding factors besides nonvaccination, such as possible vaccine failure. Additionally, as stated by the Food and Drug Administration, "while the reasons for the increase in cases of whooping cough are not fully understood, multiple factors are likely involved, including diminished immunity from childhood pertussis vaccines, improved diagnostic testing, and increased reporting. With its own funds plus support from the National Institutes of Health (NIH), the FDA conducted the study to explore the possibility that acellular pertussis vaccines, while protecting against disease, might not prevent infection." However, providing a comprehensive model of disease outbreak is beyond the scope of this study, and we focus only on the relationship between exemptions from vaccination requirements and disease incidence. The quote is from Food and Drug Administration [Internet]. Silver Spring (MD): FDA. News release, FDA study helps provide an understanding of rising rates of whooping cough and response to vaccination; 2013 Nov 27 [cited 2015 Jun 4]. Available from: http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm376937.htm

3 To access the Appendix, click on the Appendix link in the box to the right of the article online.

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16 Health Resources and Services Administration. AHRF [Internet]. Rockville (MD): HRSA; [cited 2015 Jun 4]. Available from: http://ahrf.hrsa.gov/
17 Yang YT. State Vaccination Requirements and Exemption Law Database, 2011 (ICPSR 34486) [Internet]. Ann Arbor (MI): Inter-University Consortium for Political and Social Research [cited 2015 Jun 5]. Available from: http://doi.org/10.3886/ICPSR34486.v1. Note that there are differences in reported policy and legal requirements across studies, such as between our study and that of Blank et al. (Note 12). This may reflect differences between what public health officials believe is the law and what the law actually says, or it may reflect differences between what a law says and what happens after a policy is implemented. Trying to measure which states and laws had less than full implementation was beyond the scope of this study. Therefore, we assumed that any current vaccination law was being carried out by the state.
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19 One specification that we did not use—although it was a strong candidate—was a fixed-effects regression (in this case, a model with state indicator variables). Fixed-effects models measure the impact of time-varying factors on the outcome, with all time-invariant heterogeneity (or unobservable factors) captured by the state indicator variables. One distinct advantage of fixed-effects models is that they are robust to time-invariant omitted variable bias (to which random-effects models are susceptible). However, fixed-effects models have one disadvantage for our purposes: Variables that did not change within a state during our study period could not be included in the regression because they would be perfectly collinear with the state fixed effect. Thus, if we used a fixed-effects model, we could not consider few policy components that did not change. We therefore had to decide whether to use all of the policy components in a random-effects model (in which case we would have to rely more on cross-sectional variation and could claim only to find associations) or to use only some of the policy components in a fixed-effects model (in which case we would have more capacity to make causal inferences, but their scope would be limited). We conducted a specification test by estimating our model with fixed effects and then compared the coefficients on the remaining variables to those from the full set in a random-effects specification. We found that the remaining policy coefficients were qualitatively very similar to those in the random-effects model—that is, dropping some policy components did not materially change the measured impact of the remaining components. Consequently, we concluded that the random-effects model with all policy components did not suffer from meaningful omitted variables bias, and that we were able to use it in our analysis. We proceeded on that basis.
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