Understanding Vaccine Economics with Simulations

Authors: David Bishai and Sasmira Matta

Learning Objectives:

- To understand the Philipson effect or rather how acceptability of a vaccine is determined
- To understand the difference between cost versus benefit
- To understand there is no right answer in determining how to go about decision-making
- To use simulations to better understand vaccine economics

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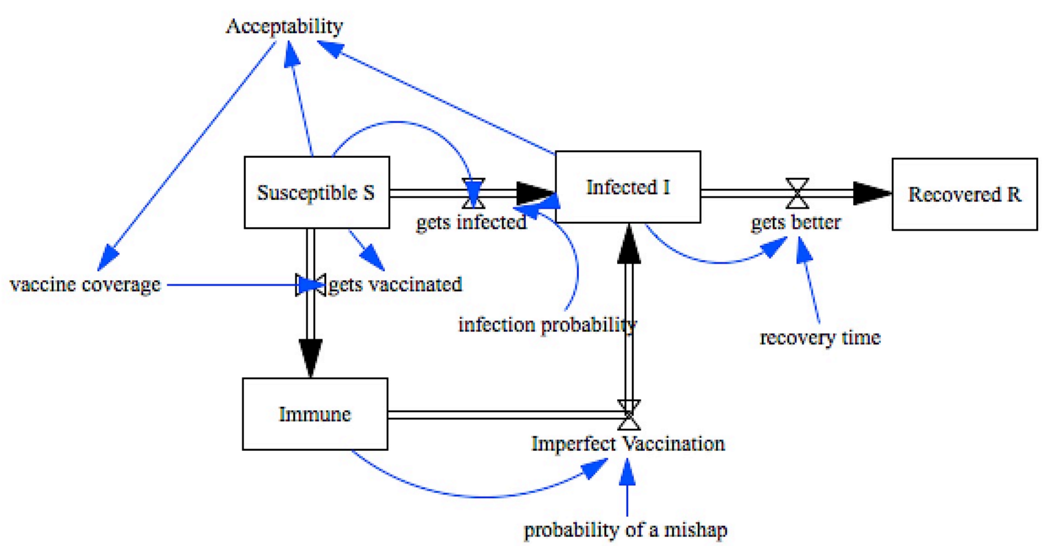
In this exercise you will be using four simulations. One will examine the dynamics in a single country, and the other three will examine the dynamics of neighboring areas. You will be using the Forio software to analyze how the population of infected children and the coverage changes as a result of different scenarios.

Single Country Model:
The following diagram is a causal loop diagram. It represents the dynamics that are occurring in a singular country.

Figure I.



In order to understand this diagram, it is important to understand what is included in the model. This is a modified SIR model, where SIR is an acronym for **Susceptible, Infected, and Recovered**. A SIR model is an epidemiological model that computes the theoretical number of people infected with a contagious illness in a closed population of time [1]. The arrows show the direction of influence for each variable. Since we are also measuring vaccine coverage, this model also tracks the number of children who receive the vaccine.

In the model we have four boxed variables: Susceptible S, Infected I, Recovered R, and Immune. Each of these variables will compute the number of children who fall in to each category at each point in time.

The arrows with the larger heads and rectangular bodies are the flows and they represent the rates. In this model we have four flows: gets infected, gets better, gets vaccinated, and imperfect vaccination. Each of these flows measures the rate at which a child moves from one box to a connecting box.

Ex. If we say that the rate of "gets vaccinated" is 80/1000, this means that for every 1000 children, 80 will get vaccinated at each time step. The other variables that are connected to the diagram by the smaller arrows are other important variables that influence the boxed variables and the rates. The following table summarizes the variables used in the above diagram and the elements they measure.

Table I. Diagram Key

Diagram	Definition
Susceptible S	Measures the number of children that are susceptible to measles
Infected I	Measures the number of children that are infected with measles
Recovered R	Measures the number of kids who recover after having the measles
Immune	Measures the number of children who receive the vaccination
Gets Infected	Rate at which a susceptible child gets sick with measles
Gets Better	Rate at which an infected child recovers from measles
Gets Vaccinated	Rate at which susceptible children get vaccinated
Imperfect Vaccination	Rate at which vaccination is imperfect and does not prevent disease for child
Infection Probability	Likelihood of being infected with measles
Recovery Time	Time it takes for a child to recover from measles
Acceptability	Measures the country's perception of vaccine safety and efficacy
Vaccine Coverage	Proportion of children that are vaccinated
Probability of a Mishap	Probability that the vaccine will not induce immunity

The following simulations have been designed to reinforce different topics in vaccine economics. When answering question focus on changes and shift, and do not get stuck on whether or not differences are significant unless otherwise asked.

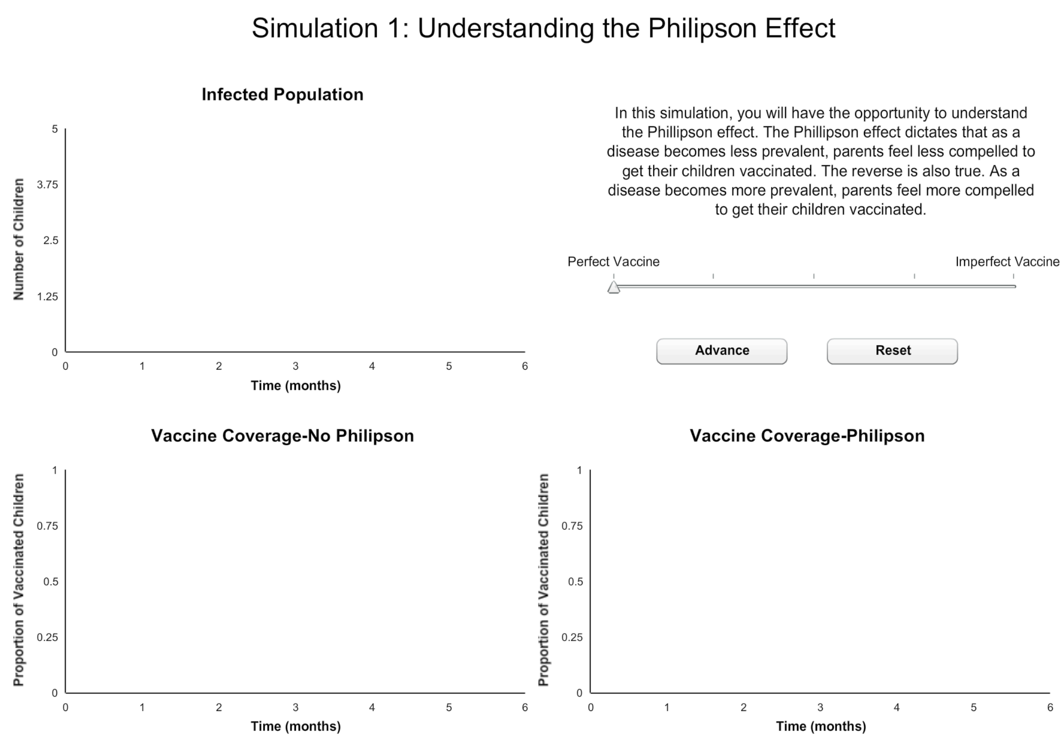
SIMULATION 1: Understanding the Philipson Effect

The Philipson Effect is a theory stating that as a vaccine preventable disease disappears, so too does the demand for vaccines. In other words, as a disease becomes less prevalent, parents are less likely to get their children vaccinated [2]. According to Geoffard and Philipson, the demand for a vaccine is proportional to the benefit of being vaccinated. They point out that if an individual realizes that coverage is very high a rational person would realize that herd immunity is protecting them and that their personal benefit from a vaccination is low. A rational and selfish person would be less and less likely to want a vaccine as the risk of disease goes down to the prior success of the vaccine program.

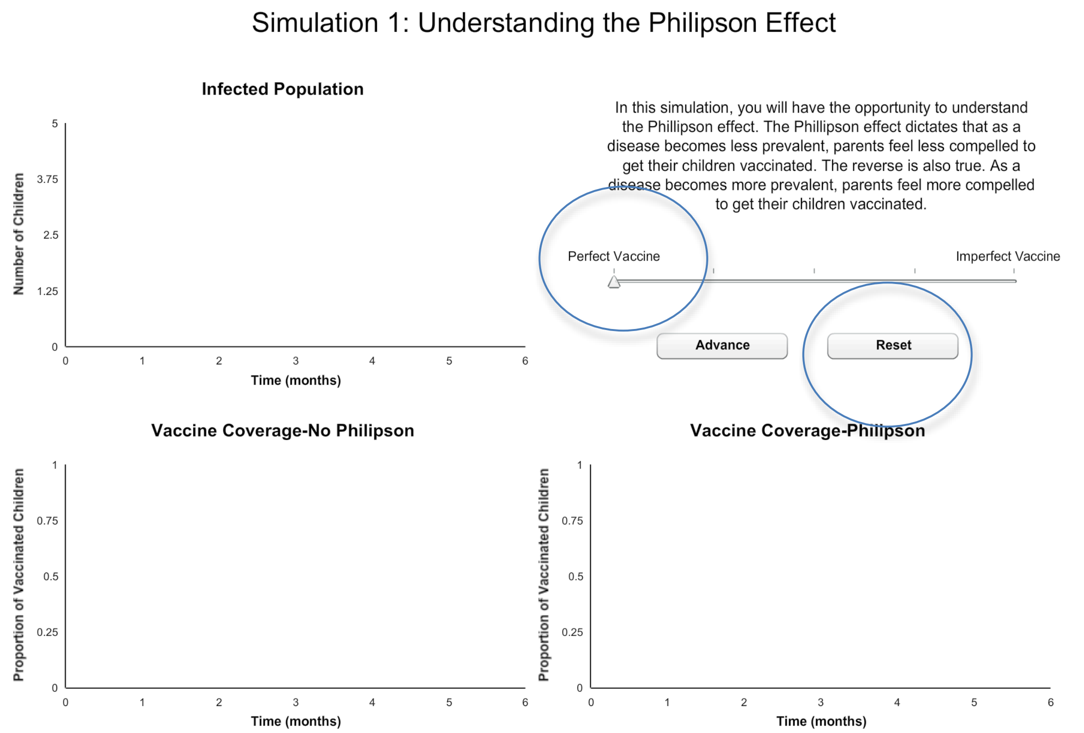
In these exercises, we will consider a vaccine to be perfect if it will definitely immunize a child. Therefore, every child who is vaccinated will definitely be immune to the disease. On the other hand, an imperfect vaccine is a vaccine in which there is a chance that a child will not be immune to a particular disease even if the child receives the vaccine.

In this simulation you will be able to track three things—the infected population, vaccine coverage with the Philipson effect, and vaccine coverage without the Philipson effect. As you run the simulation, focus on how the coverage curves differ.

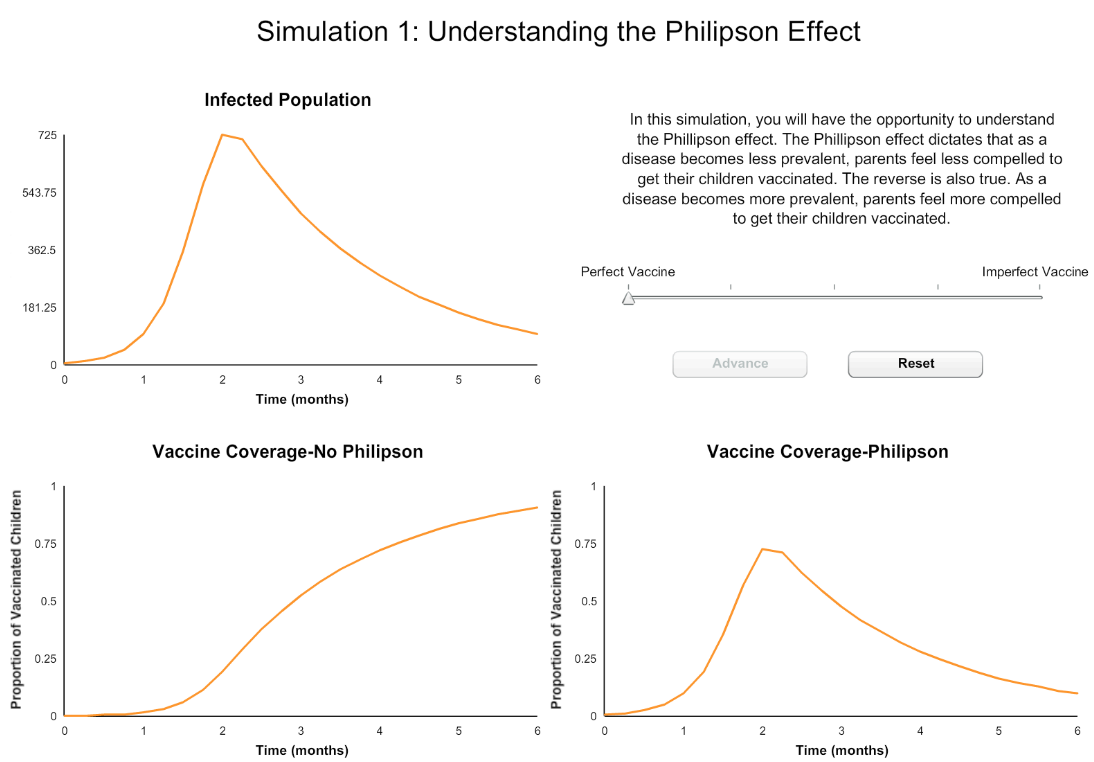
1. Go to the website https://forio.com/simulate/smatta1/single-country
2. You should see the following on your screen



3. Click the *reset* button. Start with the slider tool on the *perfect vaccine* setting.

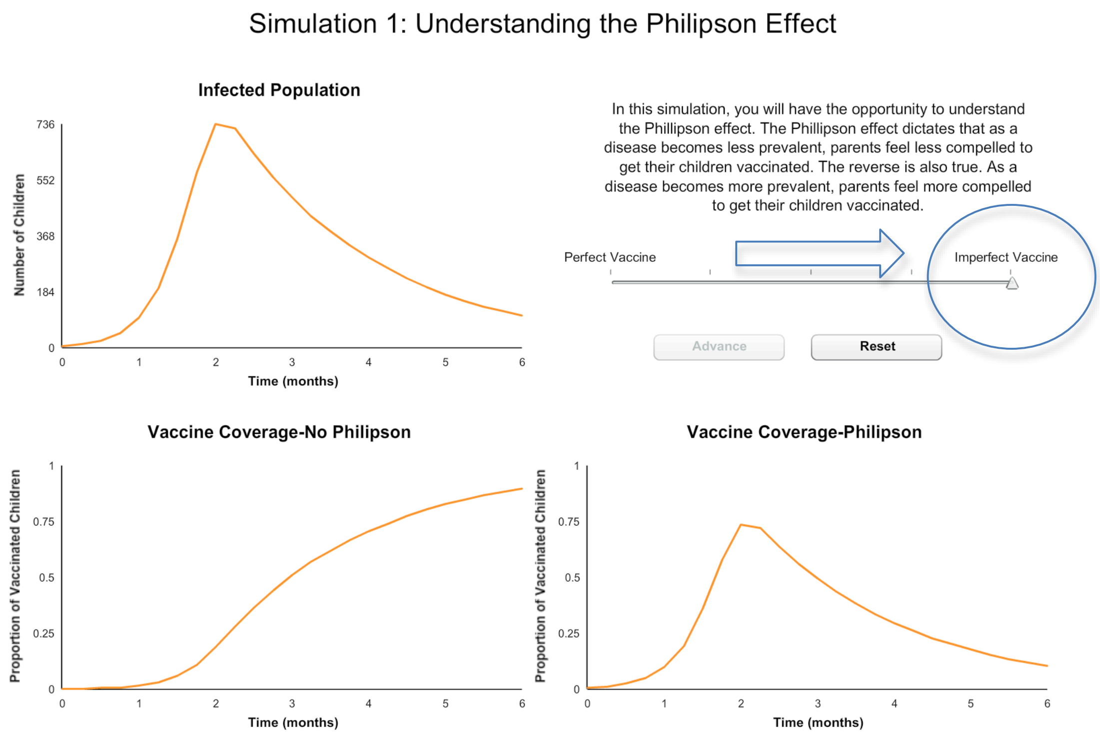


4. Click the *advance* button *six times* so that the simulation runs to completion. This is what you should see on the screen.



Which vaccine coverage curve resembles the infected population curve? Does this make sense to you? Explain.

5. Click the *reset* button. Move the decision slider all the way to the right to the *imperfect vaccination* setting. Now click the *advance* button until the simulation finishes running. After running through the simulation, you should see the following on your screen.



How does the PEAK of the infected curve differ with respect to the previous simulation? Are there more or less children who are infected? Explain.

In the simulation you see that when the vaccine is imperfect, about 11 more children will get infected. If parents start seeing that their vaccinated children are in fact getting sick, at what point does this pose a problem? How can you communicate vaccine efficacy to parents?

Under which settings—Philipson or No Philipson curves do we achieve more coverage? Why could this be the case?

Now that we have seen that the Philipson effect has the potential to drastically change the coverage, what do you do? How do you work and communicate with parents and convince them that they should be getting their children vaccinated? How do you prevent them from worrying?

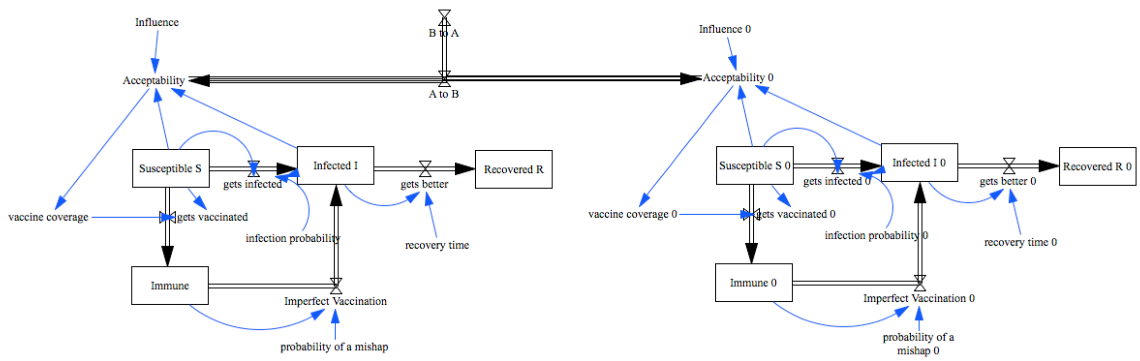
Now that we have walked through the Philipson effect under both perfect and imperfect vaccine conditions, it is now time to move to a two-country scenario.

There was a botched measles campaign in District A where 15 children who received the vaccination died. It was reported that the vaccinations were not stored properly, and that the needles were used multiple times.

You are in charge of the EPI office in District B. District A neighbors District B. You are responsible for improving measles coverage in District B, especially now that parents are weary of getting their children vaccinated after hearing the news.

The next two simulations follow similar dynamics as we have already seen in the singular country causal loop diagram. In fact if you look at the model below, the single country model was copied and pasted twice. On the left hand side we have District A, and on the right hand side we have District B.

Figure II. A More Dynamic Model (Left Side Represents District A and the Right Side Represents District B).



There are two main differences that distinguish the two-district model from the single country model.

I) There is a communication variable which is denoted as Comm for District A and Comm 0 for District B. This variable controls whether or not the communication or the dissemination of information surrounding vaccines is positive or negative.

II) There is an arrow going from District A's Acceptability to District B's Acceptability and vice versa. This demonstrates the transmission of information between the districts—information travels!

What social, cultural, and media events are examples of negative information on vaccine acceptance?

What are social, cultural, and media strategies are examples of positive communication on vaccine acceptance?

Now we will explore the two-district model on Forio in three scenarios, which are outlined below. Remember that in each of the following scenarios you are in the EPI program of District B.

SIMULATION 2: Do Not Censor the Media

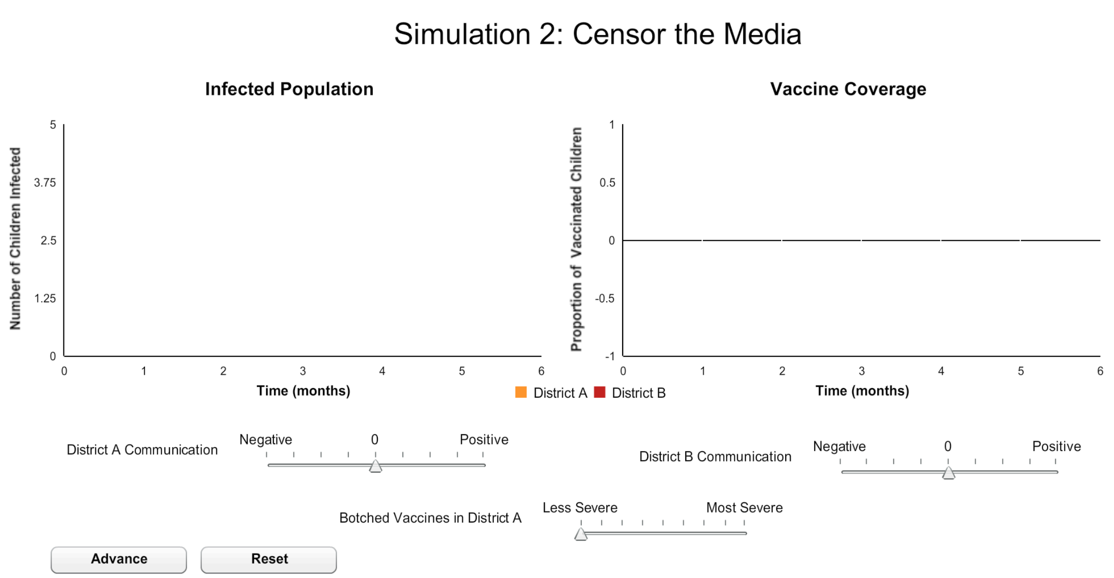
In this simulation, you have decided to censor the media. This means that the bad news about botched measles vaccine in District A cannot reach District B.

In this simulation you can manipulate the communication surrounding vaccines in the districts. The more negative the communication is, the more you can decrease acceptability in the country and vice versa.

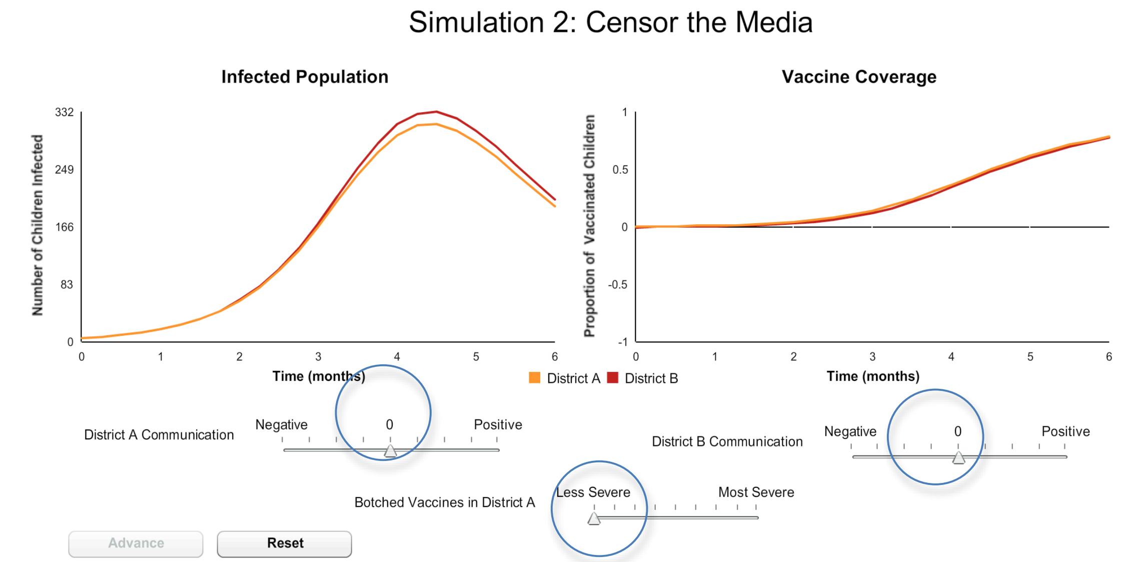
The Botched Vaccines in District A slider can be adjusted to indicate the severity of the botched campaign in District A. The Botched Vaccine in District A will affect the probability of a vaccine mishap. The more severe it is, the more imperfect the vaccine is, and the more problems it will cause.

If you hover over the curves, the tool tip will tell you the country that you are looking at and the value at the moment.

1. Go to https://forio.com/simulate/smatta1/south-sudan-and-uganda-1. The following is an image of what you should see on the screen.



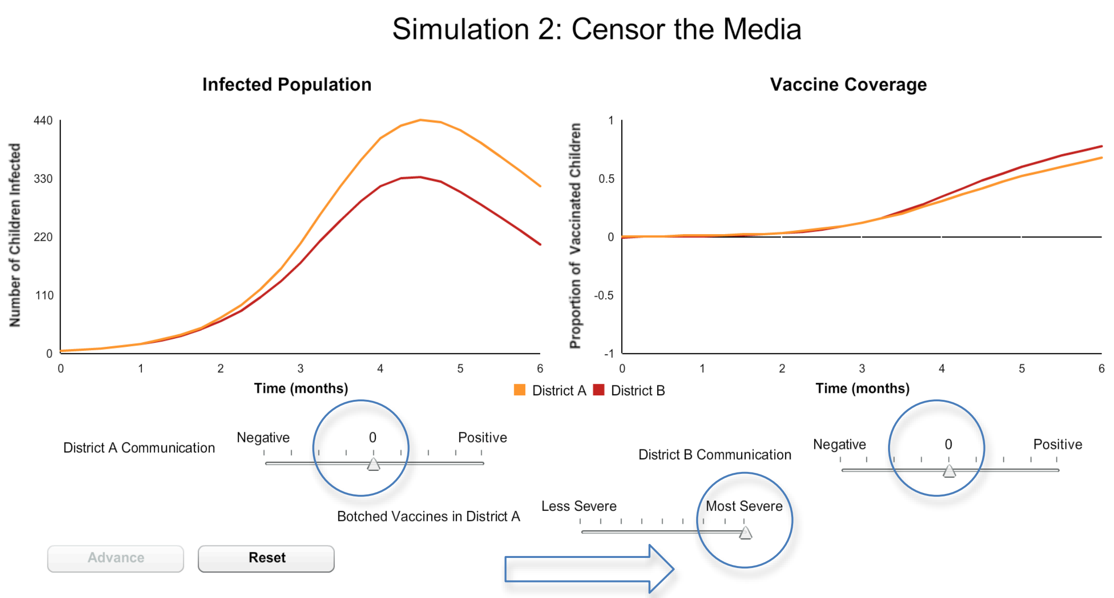
2. Set the communication in both countries to 0. Set the Botched Vaccines in District A to the left most Less Severe Setting. Advance the simulation to the end. This is what you should see on the screen.



At approximately what time does the peak of the infection occur? ____________

What is the maximum vaccnation in coverage in District B at the time of the peak of the infection? (Since the lines are quite close together, you may use the District A's estimate for District B if you are unable to hover over the District B curve). ____________

3. Set the Botched Vaccines slider to the right most side or the Most Severe Setting. Keep the influence in both countries at 0. This is what you should see. *Advance* the simulation to the end.



What is the coverage in District B at the peak of the infection?

You should be seeing a decrease in coverage. If not just play around with the tool tip until you do. Explain the decrease in coverage. Use the model to help your reasoning.

4. Now choose the intensity of the botched vaccines in District A. As you advance the simulation, change the influence in District B.

If you induce positive communication, how will this affect coverage in District B? If you take away induce negative communication, how will this affect coverage in District B?

How does changing the influence in District A affect the coverage in District B?

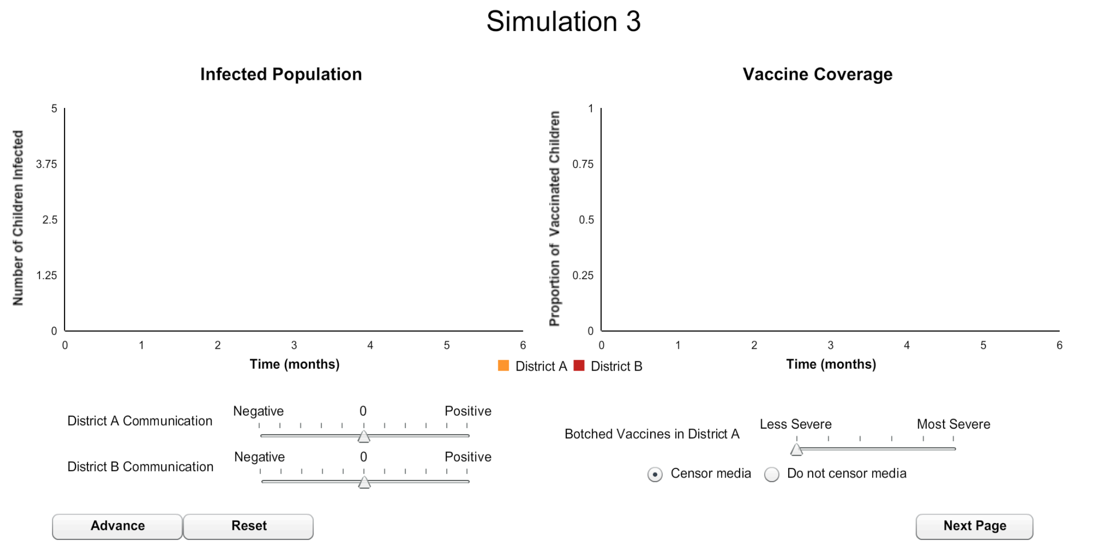
With these visualizations, where would you allocate money to improve vaccine coverage in District B? In other words, do you think it is more effective to put money in to influence in District A or in to District B? How would you arrive at the decision?

What are your final thoughts on this simulation?

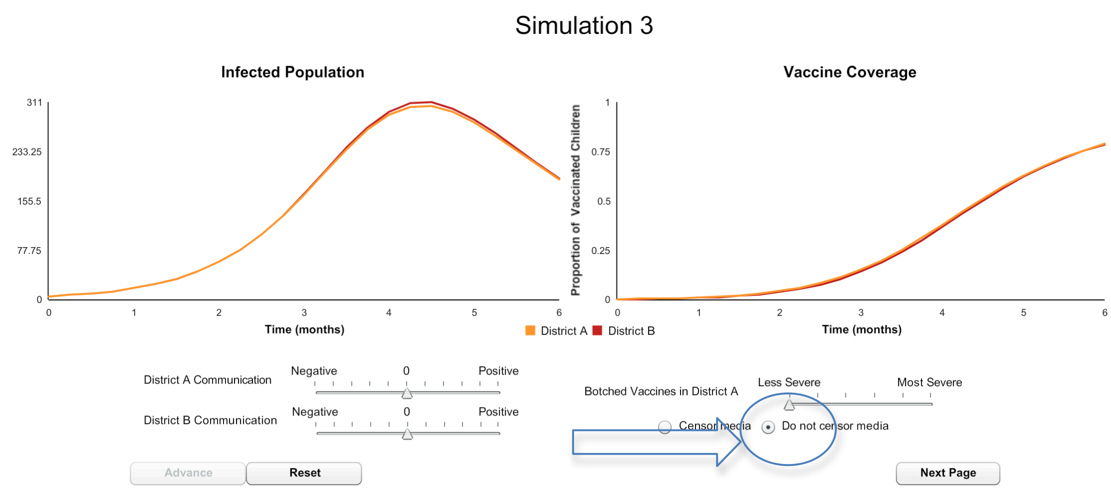
Now let's move to the next simulation!

SIMULATION 3: Censor the Media

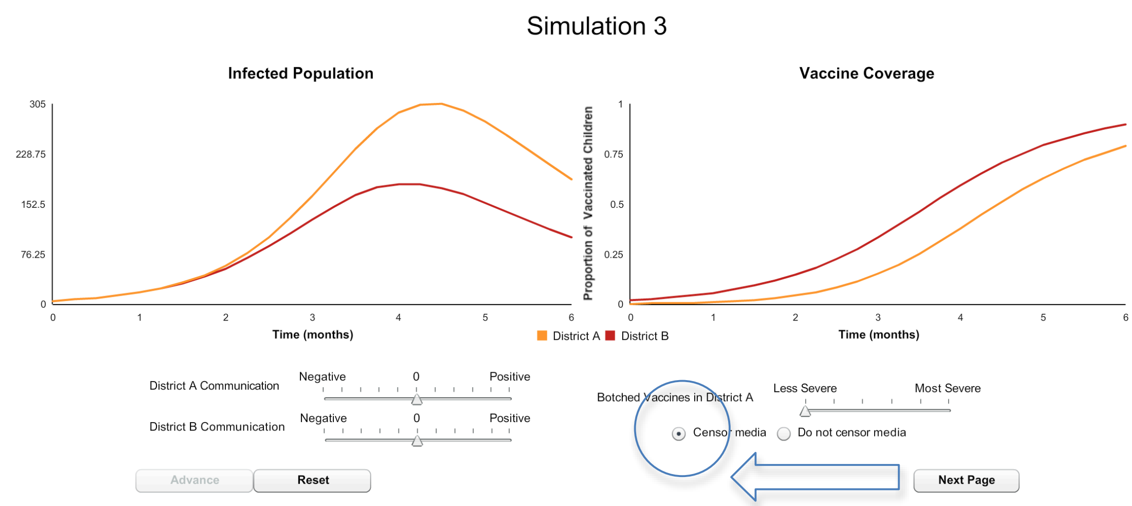
1. Go to https://forio.com/simulate/smatta1/south-sudan-and-uganda. This is what you should see on your screen.



2. Now *reset* the simulation. Click *do not censor media*. Keep the botched vaccine setting at the leftmost *less severe* setting. Keep both communication variables set to 0. *Advance* to the end of the simulation. This is what you should see on the screen when the simulation finishes running.

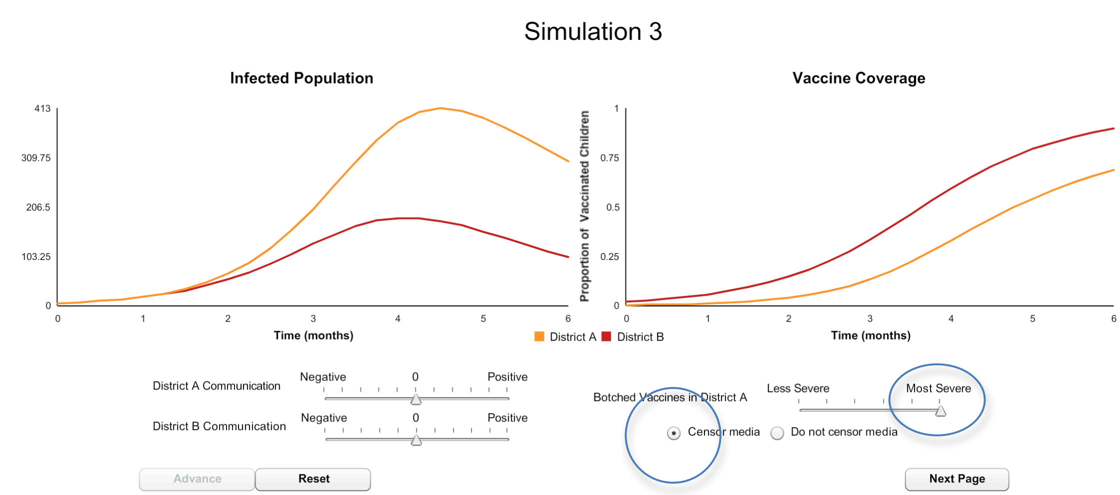


3. Now maintain the same settings as before (*both communications should be set to zero, less severe botched vaccine campaign in District A)* except this time, *censor media. Advance* to the end of the simulation. This is what you should see on your screen.

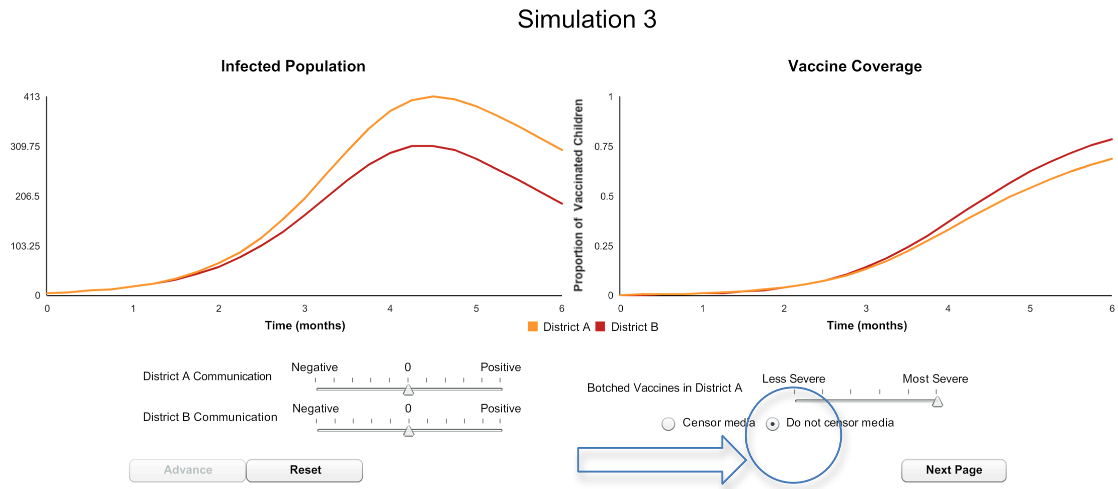


Notice that the curves are father apart when we censor. Why is this the case? Be sure to explain how the infected population curves AND the vaccine coverage curves change. Be sure to explain why this also makes sense.

4. *Reset* the simulation. Now increase the severity to the right most side setting, *most severe.* The *communication* should be set to 0 for both districts. *Censor the media. Advance* the simulation to the end. You should see the following on your screen.



5. Reset the simulation. Now keep the settings the same as above except *do not censor* the media. This is what you should see on your screen.



Compare the two sets of curves when the severity of the botched vaccines in District A is the most severe. How does the severity of the botched measles campaign affect the distance between the curves?

6. Now increase or decrease the communication & chance the censor settings as you advance through different simulations. *What do you notice?*

Final Questions and Thoughts:

Is censoring the media worthwhile? Does it have a great effect?

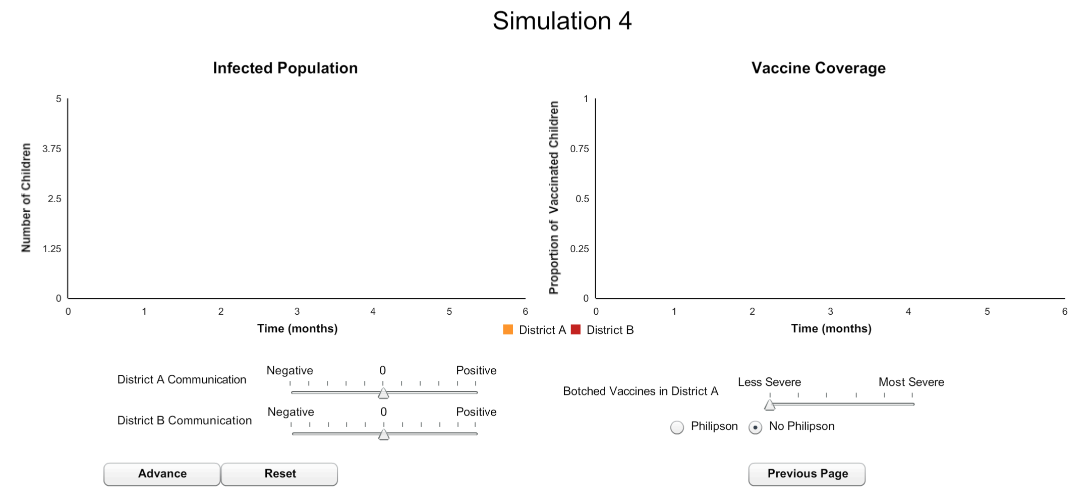
According to the simulations how can we achieve the greatest coverage when the botched measles campaign in District A is very severe? If you have unlimited resources? If you have limited resources?

How do you think those in District B would react if they learned that the media was censored?

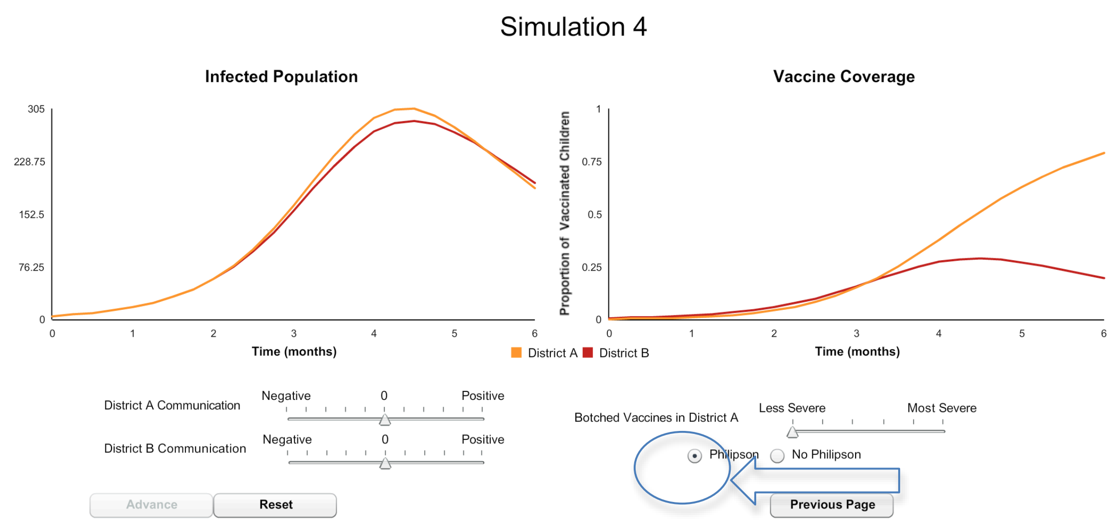
7. Now click Next Page and proceed to the next simulation.

SIMULATION 4: Philipson in the Districts

1. After clicking the *next page* button, this is what you should see on your screen.

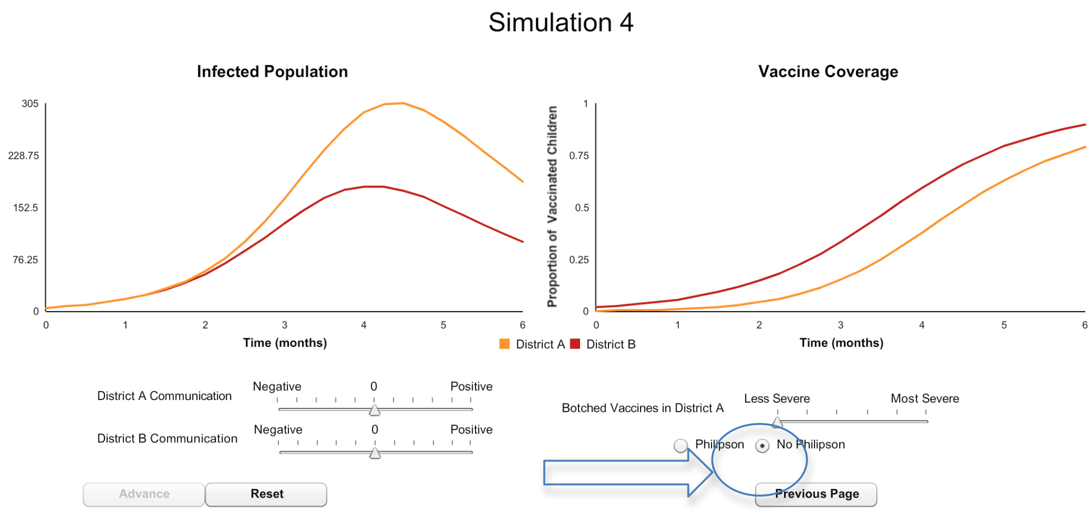


2. Click the reset button. Select Philipson. Advance to the end of the simulation. This is what you should see on the screen.



Pop quiz: Describe the Philipson effect in your own words.

3. Reset the simulation. Click No Phillipson. Advance the simulation to the end. This is what you should see on the screen.



Describe the differences that you see in vaccine coverage as you turn the Philipson effect on and off.

4. Play around with this simulation and adjust the botched vaccine severity and the communication levels.

Describe what you see?

What are your final conclusions? What would you like to see moving forward? Use this space to discuss any new and/or final thought you have.

Works Cited

1. Weisstein, E.W. *SIR Model*. Available from: http://mathworld.wolfram.com/SIRModel.html.
2. Geoffard, P.-Y. and T. Philipson, *Disease Eradication: Private versus Public Vaccination.* The American Economic Review, 1997. **87**(1): p. 222-230.