Voluntary vaccinations and vaccine shortages: a theoretical analysis

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Voluntary vaccinations and vaccine shortages: a theoretical analysis

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Abstract

A simple dynamic model of vaccination is presented and analyzed to study how the amount of vaccines available affects people's vaccination decisions. In addition, the model is used to examine how the level of vaccination in equilibrium compares to the efficient or socially optimal level. It is shown that, when the stock of vaccines is large so that a shortage could never arise, an equilibrium is generically unique, and there is too little vaccination compared to the social optimum. When the stock of vaccines is small so that not everyone in a population could get vaccinated, a shortage could occur in equilibrium. Moreover, the occurrence of a shortage could be self-fulfilling: when agents expect a shortage to develop, they have a greater incentive to demand the vaccine right away, which increases the likelihood that a shortage will result; and when agents do not expect a shortage to arise, they are more willing to delay their vaccination decision, which reduces the likelihood of a shortage developing. This leads to the possible co-existence of multiple equilibria that differ in the level of vaccination. Multiple equilibria can arise, however, only if agents are uncertain about the cost of being infected—if agents are sufficiently certain about the cost of infection, then an equilibrium is unique. Furthermore, when the stock of vaccines is small, an equilibrium level of vaccination may be too high relative to the socially optimal level. Increasing the vaccine stock could have ambiguous effects on the level of vaccination in equilibrium but unambiguously increases social welfare.

Key words: economic epidemiology; optimal vaccination; equilibrium vaccination; externalities

1 Introduction

For many infectious diseases such as the flu, the most effective way to prevent acquiring an infection is vaccination. Because whether one is vaccinated against a disease or not impacts how likely other people will get infected with the disease, modeling people's vaccination decisions—and deriving policy recommendations to maximize the well-being of a population—are important issues that have received considerable attention from scholars [Fine & Clarkson, 1986; Brito et al, 1991; Francis, 1997; Geoffard & Philipson, 1997; Bauch et al, 2003; Francis, 2004; Bauch & Earn, 2004; Chen, 2006; Boulier et al, 2007; Galvani et al, 2007; Kureishi, 2009; Funk et al, 2010; Gersovitz, 2011; Liu et al, 2011; Reluga & Galvani, 2011; Galeotti & Rogers, 2013; Chen & Toxvaerd, 2014; Goyal & Vigier, 2015; Wang et al, 2016; Cerdeiro, 2017; Manski, 2017].

It is well-known from this literature that, when vaccination decisions are voluntary, the equilibrium level of vaccination (the 'free market' level of vaccination) is in general lower than what is best from the perspective of the population as a whole, i.e., the socially optimal level. This follows since self-interested individuals do not take into consideration the impact of their vaccination decisions on others. In particular, getting vaccinated confers a benefit to other people by lowering their risk of acquiring an infection. This means that the true, social value of vaccination exceeds its private value to individuals; hence, people will tend to under-vaccinate in a voluntary context without any policy interventions.

Much of the existing literature on the theoretical analysis of voluntary vaccinations assumes that there are no constraints on the supply of vaccines, i.e., in most previous analyses, it is assumed that anyone can get a vaccine at the price given so that a vaccine shortage would never occur. (While the model in Reluga et al [2006] allows for vaccine supply to be below the level of demand, the decision process modeled here is much more explicit about how the amount of vaccines available affects individuals' vaccination choices.) There are, however, situations in which such an assumption may not be appropriate. A prime example is the 2009 H1N1 pandemic. The H1N1 virus first appeared in the US in April 2009. The World Health