How many percent of Hong Kong people will take vaccination?

Dah Ming Chiu, 19 March 2021 (minor revision on 27 March 2021)

To vaccinate or not, every Hong Kong person (adult) gets to make this decision, and it is a tough decision for many. In the end, how many percent of Hong Kong people will vaccinate? To give an intelligent guess, let us discuss the factors that affect this decision.

To be more precise about the question, we define $v_i(t)$ to be the decision by the ith person in the city: at time t, $v_i(t)=0$ means that person has not been vaccinated, whereas $v_i(t)=1$ means he has been vaccinated by time t. The percentage of people vaccinated at time t, V(t), is simply $\sum v_i(t)/N$ where N is the population in the city and the summation is over all the population[1]. Clearly V(t) is a non-decreasing function, taking values in the range between 0 and 1, and increasing at a rate bounded by the city's capacity of vaccinating people. By phrasing our question in terms of V(t), we can speculate not only on the final value of V(t) assuming it saturates at some level, but also on the path getting there.

Herd Immunity
This is not a question just for intellectual curiosity. There is an important concept called herd immunity, namely when V reaches a certain threshold (e.g. 70%), the virus will not be able to spread and will eventually be eradicated. Although existence of such a threshold is a well-accepted, and practically observed conclusion, the theory is based on a theoretical model under strong assumptions, including the assumption that the population all interact with each other uniformly. But in practice, the value of the threshold depends on how people interact with each other and how much social distancing (e.g. mask wearing) is practiced, and the model for calculating an accurate threshold is very complicated.

The fact is, however, that even without reach herd immunity, any level of vaccination (V) in the community can help reducing the rate of virus spreading, and the higher the level the better. This means each person's individual decision of vaccination contributes to a social good. In economics, this is known as a positive externality (one's action brings some benefit to others besides oneself). For this reason, the government is keen to encourage as many people to vaccinate as possible, by making vaccination free. Of course, in a city like Hong Kong, personal freedom is also highly respected, and the decision of whether to vaccinate of not is left to everyone's own choice, based on one's own circumstances and feelings.

How many people will decide to be vaccinated depends on how people make their decisions. Although herd immunity is the laudable community goal, it is unrealistic to expect people to act based on this goal alone. In the following, we postulate several

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[1] Here we are implicitly assuming that if a person chooses to be vaccinated at some specific time t_0, then $v_i(t)=0$ for $t<=t_0$ and $v_i(t)=1$ for $t>t_0$, and skip details such as many vaccines require two shots.

likely ways people decide, and discuss how they impact the ultimate value of V.

Wait-and-See
Many rational people may think of the problem this way – there is a certain risk of getting killed by the virus, so I choose to get vaccinated; but if there is some risk, no matter how small, of getting killed by the vaccine, then I better make sure the latter risk is no high than the former. For the following discussion, we refer to the former the R_1 risk and the latter the R_2 risk.

The R_1 risk is different for different people, depending on how much you expose yourself for reasons of work, other daily live necessities, and urge to socialize; and also the different virus-caused mortality rate according to age and health conditions. Given a certain window of time, the average R_1 risk can be roughly calculated based on the actual number of Covid-19 related deaths during that window of time[2] normalized by the population of the city. Since the beginning of the pandemic, this is roughly 200/7M which comes to be a fraction of 1/10K. If we consider a 3-month window, this is less than 1/100K. For any given person, you can estimate your individual R_1 risk by making adjustments according to your personal circumstances.

The true value of the R_2 risk is unfortunately difficult to find out objectively. Since all the vaccines were developed in a rush, not enough data is collected. The problem of determining an event is correlated and/or caused by another event is a well-studied by challenging problem in statistics. Without adequate data for a reliable conclusion, we tend to make judgements based on any data we come across. In the case of Hong Kong, it turns out 7 people died shortly after they got vaccinated out of around 300K people vaccinated during that period. It is hard to avoid making a simple-minded conclusion that these deaths are all somehow related to taking the vaccine, which then implies the R_2 risk is comparable to the average R_1 risk. The government-appointed expert panel carefully examined the circumstances of these deaths and concluded that they were unrelated to vaccination, but it is hard for the public to immediately accept this conclusion.

This led many people to make the "wait-and-see" decision: since I am not sure about R_2, I assume the worst and wait for period of time if my R_1 during that time is not much higher than R_2, and make a future decision about vaccination when I can be more sure that R_2 is less than R_1. For the sake of argument, assume the average R_1 to be $100/7M=1.4 \times 10^{-5}$; since we do not know how the individual R_1 value is distributed, we assume it is uniformly distributed between 0 and 2.8×10^{-5}; and assume all the wait-and-see people calculate R_2 as $7/300K=2.3 \times 10^{-5}$, by assuming all the deaths were caused by the vaccine. Under these assumptions, only **18%** of the wait-and-see people will decide to go for vaccination. If over time, public opinion can be changed by more evidence, and a fraction of the wait-and-see people will accept the conclusion of the expert panel, then we will see a proportional increase in the wait-and-see people willing to be vaccinated. In any case, we should appreciate the

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[2] The calculation may need to consider shifting the window somehow to reflect the fact that infection occurs earlier.

government being very transparent about vaccination related incidents, even though it is making their job more challenging.

It is also worth noting that for many western countries, the average R_1 is 40-50 times of Hong Kong's. In that case the percentage of people willing to vaccinate would be around 98% according to the wait-and-see model. This helps to explain why the vaccination rate is higher in many countries with higher R_1.

Think of the benefits
Not everyone would think in terms of risks, especially these risks are quite small and hard to estimate exactly. One can think in terms of the benefits vaccination brings instead of risks, though it is harder to compare the benefits and risks directly. One strong motivation for many is to be liberated from various social distancing rules, so that you can work, travel and socialize as before the pandemic. To help realize these benefits, government can apply social distancing rules differently depending on whether one is vaccinated or not, allowing vaccinated people to enjoy more normal live. Apparently Hong Kong government is working on this policy.

Social influence
A friend observed that when he went for vaccination, he observed there was a disproportionally bigger group of westerners going for vaccination. I wonder if this statistic can be verified, and if so why. If true, there may be many reasons, and one obvious reason is that a typical westerner living in Hong Kong is likely to travel more, which is a good reason for getting the jab. But a less obvious possible reason is that getting vaccination is more the norm in western countries, and just by social influence, they are more inclined to get vaccinated just because their relatives and friends have already done so. I notice friends and relatives in Hong Kong also talk about vaccination amongst themselves, and they are likely to influence each other.

Concluding remarks
The question how many percent of Hong Kong will get vaccinated depends on knowing how people decide, and without know that it is anyone's guess. We tried to postulate several models of how people decide, and in particular discussed in more detail the "wait-and-see" model. Based on this model and assumption of a simplified risk distribution for the population, we envision a rather low percentage of people will decide to get vaccinated, unless the government can successfully change people's perception of the risks associated with the vaccines. This simple analysis can be extended using more realistic risk distributions. Ironically, the whole vaccination effort is made more challenging because of all the good things our government are doing: keeping the pandemic reasonably under control, and being very transparent with the experiences with vaccination.

In trying to answer the original question in the title, we found that at any time t, the percentage of people who want to get vaccinated, perhaps we use another function W(t) to represent it, is the balancing result of different factors, e.g. R_1 vs R_2, benefit vs pain, positive vs negative social influence. W(t) fluctuates over time, depending on how the above factors evolve, and determines V(t) over time.