To Mask or Not to Mask: Policy Implications*

Travis Ng

APEC Study Centre and Economic Research Centre

The Chinese University of Hong Kong

TravisNg@cuhk.edu.hk

Abstract

Scientific studies have shown that mask-wearing reduces the spread of the COVID-19 virus and helps "flatten the curve." But they do not address the problem of whether individuals have incentives to wear one. Without ex- plicitly taking into account individuals' incentives, policy-makers would not know when people would comply with a mandatory mask rule. I describe a simple decision-making model that helps address the problem and discuss its policy implications.

Keywords: Mandatory mask laws; population density; public good; COVID-19; infection.

*Prepared for the presentation at the e-APEC STUDY CENTRE CONSORTIUM CONFERENCE 2020. The research for this policy paper is funded by the Hong Kong Trade and Industry Department. It is based on an unfunded technical report of mine entitled "To Mask or Not to Mask," which is available for download at http://teacher.econ.cuhk.edu.hk/~travisng/

Introduction

If one knows how masks work to prevent the spread of COVID-19, she would not have much incentive to wear one. Mask wearing resembles other costly pro- tective actions that involves a free-riding problem: doing so protects others more than the mask-wearer herself. A mask works to block small particles from pass- ing through. But if the particles are too small, such as a virus, it does not block them at all. Luckily, most viruses do not hang in the air by itself. They attach to certain things, such as droplets.

The science of transmission. COVID-19 viruses usually come out of an infected person through attaching themselves with the person's droplets. If one is in- fected, when she talks, coughs, sneezes, or simply exhales, the droplets created can have significant amount of viruses enough to infect others. At least two transmission mechanisms are involved in an infection. First, the droplets with the virus hanging in the air are inhaled by others. Second, the droplets fall on a surface and are touched by others before they are evaporated and the viruses haven't been eliminated by chemicals such as alcohol, usually with hands, which are in turn used to touch the faces. If worn properly, a mask can very effectively block droplets with virus from leaving the mask because droplets are usually large in size. In turn, it very effec- tively prevents the droplets from infecting others through the above two trans- mission mechanisms. On the other hands, if droplets have been hanging in the air, due to evapo- ration, the droplets will become smaller and smaller as it travels in the air. A mask-wearer may inhale the droplets because masks become much less effective in blocking smaller particles.

The bottom-line. It is basic science that wearing a mask protects others more effectively than protecting the mask-wearer herself. This creates a policy concern: if people know exactly the basic science of how masks work, wouldn't they have no incentive at all to wear one? Shall we educate the people? Or shall we just pretend wearing a mask giving us the false security?

Free-riding. If one has a choice, she would prefer others to wear masks such that she would not have to. It is because sometimes a mask is costly and uncomortable to wear. But if everyone thinks so, no one would want to wear one. And we are back to square one. We know mask-wearing can be effective, but how do we motivate people to wear one?

A mandatory mask rule? Some policymakers would suggest a mandatory mask rule: let the government enforces a rule ordering everyone to wear a mask in pub- lic areas or risk being fined heavily or spending some time behind bars. At least two problems follow. First, what makes us believe that everyone would com- ply to such a rule? Second, if there is very low compliance, wouldn't it cost the government (more precisely, the taxpayers) a fortune to enforce the rule?

Conceptualizing the problem in economics

Economics has a set of tools especially handy to address policies that have to deal with free-riders. There has long been a problem of the so-called "public good." A public good is a desirable thing, such as clean air or national defense, that is both non-rivalrous and non-excludable. Something is non-rivalrous if Peter's consumption of it would not diminish Mary's enjoyment of consuming it. Some- thing is non-excludable if once it is there, no one can block John from consuming it even though John doesn't pay for it.

Wearing a mask is a classic public good. It is non-rivalrous in a sense that Peter's consumption, who happens to be nearby the mask-wearer and is thus getting protected, does not diminish the mask's protective effects on Mary who is also nearby the mask-wearer. It is non-excludable in a sense that it is impossible for the mask-wearer to charge Mary and Peter who happen to be near her but not paying her for her wearing a mask.

One potential consequence is that no one would have an incentive to offer a public good. But as we observe all around the world, there are indeed many people who wear masks even though they are not forced to. Therefore, although not being offered is one potential consequence of a public good, it clearly does not mean that one is *never* offered. There is another observation difficult to explain. Polar opposite cases among equally-crowded cities exist: some in which almost everyone wears masks, but few do so in others. Addressing the problem of when a mandatory mask rule would be effective cannot avoid the careful examination of individuals' choices of whether to wear a mask or not. I therefore use an economic model to model their choices. My model can also explain the polar opposite cases.

A verbal description of the mathematical model

Why would people choose to wear masks in some places but not in others? Do they simply misunderstand how masks work? Did they get the math wrong and miscalculate the risks? Do they care and thus act more responsive to the #StopTheSpread hashtag than others? Are they overly cautious? Is their action simply a political act against the advice of the government or the WHO? Do non- mask wearers feel social pressure from mask wearers? Does signaling to others that you care matter during such difficult times?

Although these explanations are not necessarily incorrect, they are behavioral assumptions that are kind of arbitrary. We cannot easily measure the extent of these behavioral traits. We therefore cannot put them into a mathematical model easily and make good use of them in policy-making. From a more conceptual per- spective, it is not advisable by explaining the differences of, say, Manhattan and Hong Kong, by assuming that the people in these two cities are simply different. I therefore build a static model that rules out all these behavioral assumptions.

It is static in a sense that the abstract model is best understood as a snapshot in time. Let us say it lasts for one week. Within this one week, everyone chooses to decide whether to wear a mask, which costs her something, or not to wear a mask. Obviously, the trade-off one concerns would be what benefits wearing a mask would bring her. In a nutshell, the benefits can be summed up as the reduction in the chance of getting infected. The difficulty lies on figuring out *by how much*. The model allows us to see the most fundamental factors that would increase or decrease such benefits. For those who are interested in the details of the model, please read Ng (2020).

The model has the following key ingredients concerning so-called rational individuals, i.e., everyone is emotional-less and she wears a mask as long as her privately-perceived benefits outweigh the cost.

1. **Externalities**. Wearing a mask protects others, but it is impossible for mask wearers to charge them.
2. **Weak protection**. Masks are meant for those who are sick. It offers some but limited protection to healthy people.[1] If a pair of infected and non-infected persons bump into each other, the virus spreads much slower if the infected person wears the mask instead of the healthy one.
3. **Zero protection**. To those already infected (i.e., asymptomatic), wearing a mask only prevents them from infecting others and does not benefit themselves.
4. **Asymptomatic and presymptomatic infections**. A key difficulty in dealing with the new virus is its undetected spread: an infected person without symptoms can still infect others (He et al., 2020). A person has to decide whether or not to wear a mask even without knowing if she is already infected.
5. **Self-interest**. People do not derive utility from protecting others or others' health. They only care about their own health.
6. **No one is misinformed**. Everyone knows how masks work.

These ingredients are put into play in a strategic game in which each player decides whether or not to wear a mask. A key driver in the model is the number of individuals that one person randomly "bumps" into; I regard such scenario as inevitable in our daily life. The word "bump" here does not strictly refer to seeing and interacting with someone directly. It can mean taking an elevator, riding a bus or train, or entering an enclosed area (such as a public toilet) that others have used previously, thereby resulting in an infection. The science lies in the fact that virus transmission can be airborne, that is, a virus stays in the air even after an infected person leaves the area. Scientific studies find that coughing, sneezing, and simply breathing and talking can spread the virus; however, their findings regarding flatulence are not conclusive. These actions create droplets that can hang in the air for a certain period. One way to understand why lockdown re- duces the spread of viruses is that it abruptly cuts down the number of individu- als inevitably bumping into one another. While one may interpret this driver as population density, the two notions are not exactly the same. One caveat of the model is that this driver is *not* endogenous (i.e., it is assumed but not internally derived from within the model).

[1]The weak protection provided by masks can be understood as a reduction in the chance of getting infected by being around an infected person. Suppose that such chance is 90% if one is not wearing a mask and 70% if one wears one; the reduction in this case is 20% only.

Modeling the transmissions. Infections are characterized by probabilities. The following is a set of four probabilities for a healthy person to remain healthy *after* bumping into an infected person. The key of the model is that such a "remain- virus-free" probability is dependent on who wears a mask.

Table 1: Transmission: probabilities of a healthy person staying healthy after "bumping" into an infected person

Infected	Healthy	
	Mask	None
No Mask		

The notations , , , and are all probabilities. I assume that the healthy person is the i i k l most likely virus-free after bumping into an infected person when i both wear masks. Therefore, should be the largest probability. I also assume the healthy person is the least likely virus-free after bumping into an l $i > k$ $k >$ i infected person when both do not wear masks. Therefore, should be the smallest probability.

Then we have to decide whether or Following a hamsters study conducted by a group of University of Hong Kong medical professionals, I as- sume the healthy person is more likely to be virus-free after bumping into an infected person when the *infected* person wears $i > k$ a mask rather than herself wear- ing one. Therefore, .[2] This allows me to introduce free-riding incentives.

The equilibrium of the model. The equilibrium concept is Nash equilibrium. In Nash equilibrium, every player expects correctly the mask-wearing decisions of everyone else. And given others' decisions, everyone chooses her mask-wearing decision optimally, i.e., her decision whether to wear a mask or not gives her the higher payoff than the decision she does not pick.

To say it in plain English, suppose Eva expects that everyone else is going to wear a mask. She knows the four probabilities , , , and . She would be able to perceive her private benefit, denoted , of wearing a mask. i i k l Suppose the cost of doing so is c $MB > c$ MB Then, as long as i.e., her private benefit of wearing a mask outweighs the cost, she would also wear one like everyone else.

[2]Hamsters have helped prove this point. Chan et al. (2020) place infected and healthy ham- sters 66.7% 33.3% in separate cages. Air was blown from the former to the latter. The infection rate after a week depended on how surgical masks were placed: if not placed at all, if placed on the cage of the healthy hamsters, and 16.7% if placed on the cage of the infected hamsters

What if she expects everyone else is *not* going to wear a mask? Then obvi- ously, Eva's perceived private benefit would be different from that if she expects everyone else is going to wear a mask. What if we also change her belief of the initial infection rate? Eva might have expected that around 0.5% of the population is M infected. But when she turns on the radio, the news doubles her expectation to 1%. Again, such a change in the initial infection rate will affect her perceived private benefit.

What if Eva has to inevitably "bump" into people in the game? Would her private benefit of wearing a mask change when this number increases? Certainly. M

Ultimately, the hunting of the equilibrium allows us to nail down the specific conditions under which it is in the self-interest of all the individuals to wear a mask. Once a mathematical model like mine is built, we can simulate it using computers to generate different scenarios for policy studies.

Sum up. To sum up, it is very simple to understand the individual's decision: as long as one's perceived private benefit of wearing a mask outweighs the cost, she wears a mask. What is not that straightforward is to figure out exactly what one's perceived private benefit depend on? My model suggests the following factors: [a] the ini- tial infection rate of the population, [b] the number of people one has to randomly and inevitably bump into, [c] the expectation of everyone else's action, and [d] the four probabilities: , i i k l, , and , that describes the scientific filtration efficiency of a mask.

What do we learn from the mathematical model?

7. **The outcome best for the society isn't always adopted**. While sometimes it is the best for the society for everyone to wear a mask, the model points out that we should not expect everyone would have an incentive to do so privately under all those situations. In other words, don't expect individu- als would voluntarily come up with the collective actions that would be the best for the society. There is thus a potential for public policies, such as a mandatory mask rule, to play a role.

   Whenever a mandatory rule is introduced, don't expect people would automatically comply. If it is not individually rational for individuals to wear masks, a mandatory rule would not magically make them all of a sudden wear masks. Unless a large amount of taxpayers' money is spent, or they will continue to not wear masks. The model points out that there are only certain conditions under which the individuals do not wear a mask in equi- librium, but they will be tilted by a mandatory mask rule to another equilib- rium in which it is individually rational for everyone to wear a mask. Such a scenario sometimes happens. It is when such a scenario happens that a mandatory mask rule would play a role. Otherwise, a mandatory rule will be ineffective.

8. **Don't be too hung up with the mask quality**. It may be strange for some to find the U.S. Centers for Disease Control and Prevention in April rec- ommending everyone to wear something, like a homemade mask or a ban- dana, to cover nose and mouth in public area. One would wonder if these materials even block droplets and viruses at all. Why not suggest a medical grade mask instead? The model and its simulation suggest to us that the scientific filtration efficiencies of a mask, although is still one factor, but it is definitely not *the* decisive factor. It is great to have higher quality masks, but lower quality masks with poor filtration efficiency do not mean they are useless in helping to "flatten the curve." If everyone wears low-quality masks, the curve is also considerably flattened, which is good news!

9. **Reduction of cost is the key**. Making sure the cost of wearing a mask is low enough is an overwhelmingly important key. Do not be too hung up with the quality of the mask. Just make sure people feels it really costs them little to wear a mask. What costs are we talking about? Many. One is the cost of queuing up for masks. Another is the actual monetary cost for one to buy masks. Keep them low! Yet, another one is the psychological cost of wearing one. Regulatory hurdles are another costs.[3] Social stigma can be another cost: people in some areas perceive wearing masks as a sign of weakness.[4] If anything, focusing on reducing the costs of wearing masks

10. **Don't be too hung up with the mask quality**. It may be strange for some to find the U.S. Centers for Disease Control and Prevention in April recommending everyone to wear something, like a homemade mask or a bandana, to cover nose and mouth in public area. One would wonder if these materials even block droplets and viruses at all. Why not suggest a medical grade mask instead? The model and its simulation suggest to us that the scientific filtration efficiencies of a mask, although is still one factor, but it is definitely not *the* decisive factor. It is great to have higher quality masks, but lower quality masks with poor filtration efficiency do not mean they are useless in helping to "flatten the curve." If everyone wears low-quality masks, the curve is also considerably flattened, which is good news!

11. **Reduction of cost is the key**. Making sure the cost of wearing a mask is low enough is an overwhelmingly important key. Do not be too hung up with the quality of the mask. Just make sure people feels it really costs them little to wear a mask. What costs are we talking about? Many. One is the cost of queuing up for masks. Another is the actual monetary cost for one to buy masks. Keep them low! Yet, another one is the psychological cost of wearing one. Regulatory hurdles are another costs.[3] Social stigma can be another cost: people in some areas perceive wearing masks as a sign of weakness.[4] If anything, focusing on reducing the costs of wearing masks[3] Some have pointed out that the U.S. Food and Drug Administration's categorization of masks as medical devices has slowed down the supplies

of masks. Source: Matzko, Paul. (2020 Apr 1) "To help solve the surgical mask shortage, get the FDA out of the way." *New York Daily News* Retrieved from https://www.nydailynews.com/opinion/ ny-oped-surgical-masks-fda-20200401-vlwe72h76bb53hibyf5ddu6mou-story.html

[4]An interesting episode happened in Czech Republic: Petr Ludwig, a key opinion leader, is the most important issue policy-makers should creatively achieve, which means it shouldn't cost taxpayers a fortune to achieve.

12. **Policy-making concerns both scientific and economic studies**. Scientists can tell you suppose for whatever reasons if the society moves from no- one-wearing-masks to everyone-wearing-masks, then the infection R_0 rate will be pushed down by a certain amount. But it is economics that tells us when and why people would *choose* to take a behavioral change from no- one-wearing-masks to everyone-wearing-masks. Therefore, policy-making is advised to include both hardcore science and economic studies to com- plement each other.

References

Chan, Jasper Fuk-Woo, Shuofeng Yuan, Anna Jinxia Zhang, Vincent Kwok-Man Poon, Chris Chung-Sing Chan, Andrew Chak-Yiu Lee, Zhimeng Fan, Can Li, Ronghui Liang, Jianli Cao, Kaiming Tang, Cuiting Luo, Vincent Chi-Chung Cheng, Jian-Piao Cai, Hin Chu, Kwok-Hung Chan, Kelvin Kai-Wang To, Sid-dharth Sridhar, and Kwok-Yung Yuen. 2020. "Surgical Mask Partition Reduces the Risk of Non-Contact Transmission in a Golden Syrian Hamster Model for Coronavirus Disease 2019 (COVID-19)." *Clinical Infectious Diseases* Forthcom- ing.

He, Xi, Eric HY Lau, Peng Wu, Xilong Deng, Jian Wang, Xinxin Hao, Yiu Chung Lau, Jessica Y Wong, Yujuan Guan, Xinghua Tan et al. 2020. "Temporal Dy-namics in Viral Shedding and Transmissibility of COVID-19." *Nature Medicine* :1–4.

Ng, Travis. 2020. "To Mask or Not to Mask." Working paper, available at http://teacher.econ.cuhk.edu.hk/~travisng/.made a video on March 14, 2020, to discuss the rationale of wearing masks; this video went viral. The influential video may have been instrumental in reducing the social stigma cost of mask wearing in Czech Republic.