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Assessing the efficacy of COVID-19 tracing regimes*

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Keywords: COVID-19, infections, reproduction rate, test, contact tracing, isolation, mobility.

- ***High proportion of transmission before symptom onset and asymptomatically makes COVID-19 hard to control***
- ***Test, contact tracing, and isolation regimes need to be supplemented by ongoing mobility restrictions***
- ***Otherwise, an elevated risk of a second infection wave***

In earlier work, we argued that to keep the effective reproduction number (R_e) for COVID-19 below one, and thus prevent a second wave of infection, mobility would have to remain around halfway between the pre-lockdown level and the full-lockdown level. We concluded that the only way to allow a return to a higher level of mobility would be to introduce a test, contact tracing, and isolation regime. This note discusses the key parameters that determine whether such regimes are effective or not. This depends in part on the characteristics of the virus itself and in part on the operation of the regime. Our conclusion is that it will be a challenge to control the COVID-19 epidemic using test, contact tracing, and isolation alone. This suggests that mobility will have to remain below the pre-lockdown level to limit the risk of a second wave of infection.

Key features of test, contact tracing, and isolation regimes

In the context of COVID-19, a test, contact tracing, and isolation regime would involve: first, testing all individuals who show symptoms and isolating those that test positive; and second, tracing all the contacts that they had while they were infectious and isolating all those that test positive.

In epidemiological models, four key parameters determine the effectiveness of this approach.

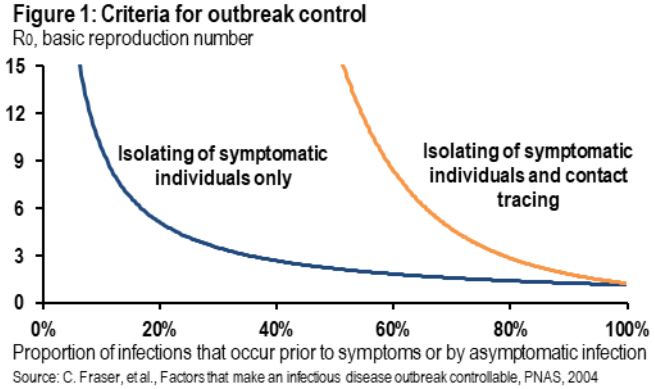
First, the number of initial cases (N). The higher the number of initial cases, the greater the number of contacts that need to be traced.

Second, the basic reproduction number (R_0). The higher the basic reproduction number, the greater the number of contacts that need to be traced.

Third, the percentage of transmission that occurs prior to the isolation of symptomatic individuals (λ). This could be due to either delays in testing, infectiousness starting prior to the onset of symptoms, or infection by asymptomatic individuals. The greater this percentage, the harder it is to control the transmission.

And fourth, the percentage of contacts that need to be traced (μ). Not all contacts need to be traced, but a sufficiently large number of potentially infectious individuals need to be removed from the population to limit ongoing transmission.

In their epidemiological model, Fraser et al.[1] illustrate the relationship between R_0 and λ when 100% of symptomatic individuals are isolated and 100% of their contacts are traced (Figure 1).



The two contour lines show combinations of R_0 and λ where new infections are stable (essentially the interventions put R_e at one). The area below each contour represents combinations of R_0 and λ where the epidemic can be controlled by test, contact tracing, and isolation, and the area above each contour represents combinations of R_0 and λ where the epidemic cannot be controlled by test, contact tracing and isolation alone.

The blue contour represents the conditions under which an epidemic can be controlled by the isolation of symptomatic individuals alone. The intuition behind this contour is straightforward. If λ is below 10%, then the

[1] C. Fraser, et al., Factors that make an infectious disease outbreak controllable, PNAS, 2004.

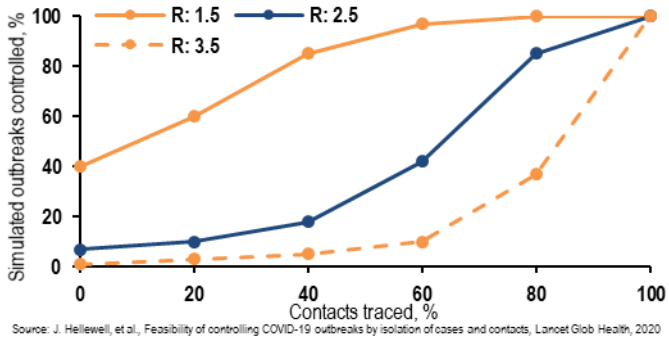
epidemic can be controlled regardless of the level of R_0 as long as 100% of symptomatic individuals can be isolated. At the other corner solution, if λ is close to 100%, then the epidemic cannot be controlled by isolation of symptomatic individuals alone because by the time symptomatic individuals have been identified the infection has been passed on.

The situation looks better when we look at the orange contour, which shows combinations of R_0 and λ which lead to infection control if there is immediate isolation of all symptomatic individuals and the testing and isolation of 100% of their contacts. If λ is less than around 60%, then any epidemic can be controlled regardless of the level of R_0. Of course, if λ is equal to 100%, then the epidemic cannot be controlled by test, contact tracing, and isolation alone.

In another model, Hellewell et al.[2] consider combinations of N, R_0, λ and μ that affect the likelihood of an epidemic being controlled by test, contact tracing, and isolation alone, without any other restrictions on mobility.

Figure 2 shows the percentage of contacts that need to be traced (μ) if outbreaks are to be controlled given different values of R_0. So, for example, if R_0 is 3.5, then in order to have a 50% chance of controlling the epidemic, over 80% of contacts need to be traced. As R_0 declines, then it is much easier to control the epidemic. This exhibit assumes that λ is around 15% and N equals 20.

Figure 2: Effectiveness of contact tracing and reproduction number

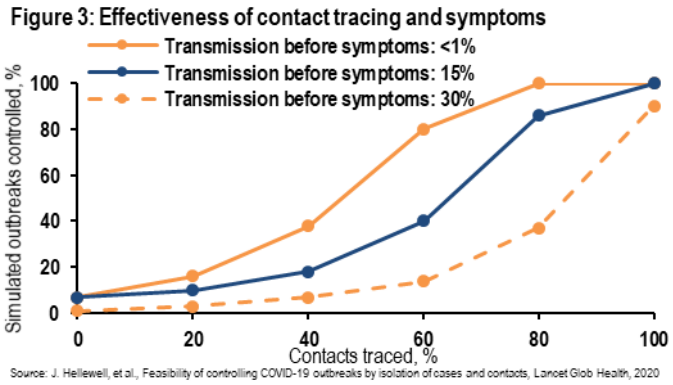


Source: J. Hellewell, et al., Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts, Lancet Glob Health, 2020

Figure 3 shows the impact of pre-symptomatic transmission. The greater the degree of pre-symptomatic transmission, the greater the proportion of contacts that need to be traced to control the epidemic. For example, if 30% of transmission occurs prior to symptom onset, then to achieve a 50% likelihood of controlling the epidemic more than 80% of contacts need to be traced. By contrast, if only 1% of transmission occurs prior to symptom onset, then to achieve a 50% likelihood of controlling the epidemic only around 60% of contacts need to be traced. This exhibit assumes that R_0 equals 2.5 and that N equals 20.

Hellewell et al. go on to illustrate the importance of the initial number of cases (N), and delays in the isolation of symptomatic individuals and asymptomatic infectiousness, both of which increase λ. The higher N is, the harder it is to control the epidemic because many more contacts need to be traced. This creates logistical challenges for the operation of the regime. Similarly, increases in the lag from symptom onset to isolation and an increased percentage of infections by asymptomatic individuals both make controlling the epidemic harder, even with very high levels of contact tracing, as the model of Fraser et al. illustrates.

[2] J. Hellewell, et al., Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts, Lancet, 2020.

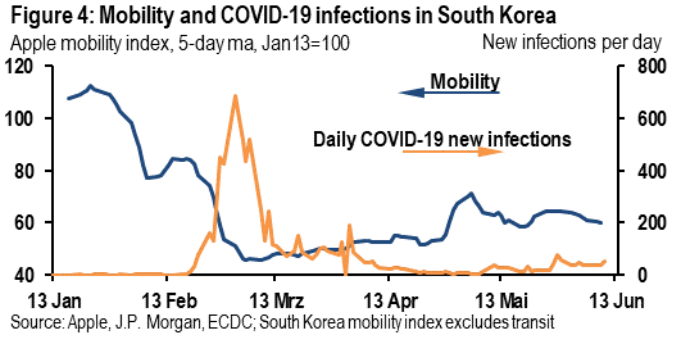


Applied to SARS and COVID-19

We can apply these results to SARS and COVID-19 to illustrate how an epidemic can be controlled by test, contact tracing, and isolation regimes. SARS was easily controlled by simply isolating symptomatic individuals because R_0 was not too high (2 to 4) and λ was very low (less than 10%). An individual only became infectious several days after the onset of symptoms (high temperature) and there was no asymptomatic transmission. Thus, widespread checking of temperatures was sufficient to identify and isolate infected individuals before they became infectious.

By contrast, COVID-19 looks much harder to control by test, contact tracing, and isolation alone because λ is very high. Around 80% of COVID-19 infections are either asymptomatic or in individuals who have very mild symptoms. Furthermore, with COVID-19, infectiousness begins one to two days prior to the onset of symptoms for symptomatic individuals. It is plausible that with COVID-19, λ could be in a range between 80% and 100%. According to Fraser et al., this would make COVID-19 a very challenging disease to control even with 100% isolation of symptomatic individuals and 100% tracing, testing, and isolation of their contacts. We recognize the uncertainty surrounding the extent to which asymptomatic individuals are as infectious as symptomatic individuals: to the extent that they are less infectious, this reduces λ.

The challenge of managing COVID-19 even with a very effective test, contact tracing, and isolation regime can be seen in the experience of South Korea. Infections have remained subdued for the past three months but this is partly due to the still-subdued level of mobility (Figure 4). It doesn't appear that the test, contact tracing, and isolation regime has allowed mobility to return to close to pre-lockdown levels without there being a risk of a second wave of infection.



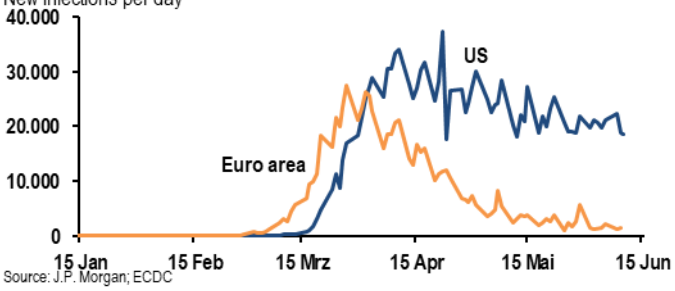
The role of the number of daily new cases has received less attention than it should have in considering the efficacy of test, contact tracing, and isolation regimes, in our view. It is striking that China and South Korea both got new infections down to very low levels before easing lockdown restrictions. By contrast, lockdown easing in Western Europe and the US started with still high levels of new infections (Table 1). Thus, it will be challenging to get test, contact tracing, and isolation regimes set up in Western Europe and the US that will be effective enough to allow mobility to return to pre-lockdown levels. Thus, if mobility rises too high, there is a risk of a second wave of infection. The US looks especially vulnerable (Figure 5).

Table 1: The easing of COVID-19 restrictions and new infectious

Country	Date of start of easing restrictions	Number of days since start of easing restrictions	Number of new infections at start of exit	Latest number of new infections
Wuhan	8-Apr	64	0	0
Germany	20-Apr	52	1,775	318
France	11-May	31	209	403
Italy	27-Apr	45	2,324	283
UK	11-May	31	3,923	1,741
Denmark	15-Apr	57	193	39
Norway	27-Apr	45	38	16
South Korea	20-Apr	52	13	50
US	10-May	32	20,258	18,665

Source: J.P. Morgan, ECDC

Figure 5: Daily COVID-19 new infections in the US and Euro area



But, test, contact tracing, and isolation regimes don't need to be 100% effective to be helpful in allowing mobility to rise further without risking a second wave of infection. Any reasonably effective test, contact tracing, and isolation regime will help to reduce R_e and thus limit the additional pressure from limited mobility needed to keep R_e below one. But, at the end of the day, to control COVID-19, it looks likely that countries will not only need a relatively effective test, contact tracing, and isolation regime, but they will also need to ensure that mobility levels remain somewhat below where they were pre-lockdown.

About the author

David Mackie *is a Managing Director and Senior Advisor for European and Global Thematic Research. He has been at JPMorgan for 30 years, analyzing a number of different European economies and various regional and global issues. From 2000 to 2018 he was the Head of Economic Research for Western Europe, managing a small group of economists, but he is now in a new role focusing on thematic research. Prior to joining JPMorgan he spent 5 years at the Bank of England, both as an economist and as a manager of the official foreign exchange reserves. David completed his undergraduate studies at Cambridge University in 1981 and his postgraduate studies at Oxford University in 1984.*

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