Expert opinion: CoronaMelder: an economic perspective

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8 Expert opinion: CoronaMelder: an economic perspective

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8.1 Introduction

The COVID-19 pandemic triggered a host of interventions across the globe that had a profound impact on daily life, civil liberties and the economy. In the Netherlands, schools were closed as well as restaurants, cinemas, theatres, libraries, sporting facilities and most shops. Public, sports and cultural events were cancelled or postponed. International travel was discouraged, and some borders were even closed, while people who nevertheless did travel abroad were urged to go into quarantine. A curfew was imposed, restrictions were introduced on the number of visitors one could receive at home, as well as the number of people that were allowed to gather in public spaces and the number of attendees at weddings and funerals. Wearing a protective mask was made compulsory in public transport, shops and most other public or semi-public buildings, while social distancing – keeping anyone from outside your household at a minimum distance of 1.5 meters – became the norm.

What all these intrusive measures have in common is their aim to prevent the spread of the virus and its devastating effects on public health and the health care system by *generically* reducing the number of contacts that can cause the virus to jump from one host to the other.

In addition to such measures, contact tracing has been used to identify those that have been close to someone who tested positive for the virus and thus run a *specific* risk of being infected. The aim of contact tracing is to identify infected people at an early stage, prevent them from having further contacts and thus, infect others before developing symptoms. Potentially, this leads to a more precisely targeted reduction in contacts, namely contacts with a higher likelihood of leading to new infections, than generic measures that reduce the number of contacts in society at large.

In economic terms, the effects of the generic measures mentioned above were immediate and immense. In December 2019 and pre-pandemic, CPB predicted the Dutch economy would grow by 1.3% in real terms in 2020, with the largest perceived threats to growth being issues concerning nitrogen- and PFAS-norms, Brexit and finally, US trade policy (Centraal Planbureau 2019). Half a year later, in June 2020, it predicted an unprecedented decline of 6% in real terms (Centraal Planbureau 2020). The most recent forecast from March 2021 was slightly more optimistic, estimating the decline in 2020 at 3.7% and predicting a recovery of 2.2% in 2021 (Centraal Planbureau 2021). Meanwhile, public expenses have skyrocketed. Billions were spent on medical care and on support for those sectors of the economy that were forced to shut down, causing government debt to grow rapidly.

And these are just the monetary and short-term effects. The effect of cancelled and postponed medical care during the first COVID-wave in 2020 in the 12 most frequently provided medical specialties was estimated at 34-50,000 healthy life years lost (van Giessen et al. 2020, p. 3). This number excludes many effects, such as the negative effect on the early diagnosis of cancer due to halting public screening programmes. Also, economists have warned about long-term economic effects, for instance those of the temporary closing of schools (Teulings 2021) and have warned that the current interventions aimed at stopping or slowing down the spread of the virus are overstated, causing more costs than benefits to society (e.g., Baarsma et al. 2021). On the other hand, early attempts at the cost-benefit analysis of restrictive measures in the United States have turned out to be positive. Doti (2021) estimates the reduction in the number of lives lost in the US at 358,000 in 2020. At an age-adjusted value of statistical life (VSL) of $4.2 million, this outweighs the estimated costs of lost jobs and negative income effects by a factor 3.7.[755] Broughel and Kotrous (2021) reach similarly positive net outcomes of the restrictive measures during the pandemic's first wave.

Against this background, this paper analyses digital contact tracing apps, specifically the Dutch *CoronaMelder* through an economic lens. Like many countries before it, the Netherlands launched an app for digital contact tracing in October 2020. The aims of this smartphone app are: (1) to assist or supplement public health institutions (GGD) in tracing the recent contacts of someone who tested positive for COVID-19, which may have led to new infections; (2) to slow down the spread of the virus by urging these contacts to be tested and quarantine until it is clear whether or not they have been infected, in order to stop them from infecting others (Ebbers et al. 2021, p.3).

The structure of this expert opinion is as follows: Section 2 describes several basis characteristics of the *CoronaMelder* app and its usage and summarizes the conclusions of the recently published evaluation. Section 3 discusses the private costs and benefits of using the app: what are the incentives for an individual to use it? Subsequently, Section 4 looks at the direct and indirect costs and benefits from a societal perspective. Section 5 concludes the report.

8.2 Facts and figures about the *CoronaMelder* and conclusions from evaluation

One of the first foundations for the use of contract tracing apps to combat COVID-19 was provided by Ferretti et al. (2020). Based on models of the spread of the epidemic and observing that a large proportion (46%) of new infections resulted from pre-symptomatic individuals, the authors concluded that manual contact tracing would not lead to epidemic control. They proposed the introduction of an app to immediately notify the previous contacts of a person who turned out to be positive. This could reduce the need for more restrictive measures. This idea gained traction rapidly. China, South Korea, Israel and Singapore were among the first countries to introduce such apps, followed in Europe by Germany and Switzerland and several countries afterwards (Rehse and Tremöhlen 2020, p. 36-37).

In the Netherlands, the CoronaMelder app was officially launched on 10 October 2020. Installing the app is voluntary (there is no obligation or pre-installation on new phones), and after being tested positive,

755 Note that this analysis disregards various costs and benefits, such as the aforementioned costs of postponed medical care and long-term educational effects, as well as the benefits of preventing long-term health damage for long-COVID patients, and of a further surge in medical costs treating patients.

users can consent to alerting their past contacts via the app.[756] The app registers a contact when another app user is estimated to have been within 1.5 m for at least 15 minutes.

On 28 May 2021, an evaluation of the *CoronaMelder* was published (Ebbers et al. 2021), which is taken as the basis for most of the factual information in this section. Some key figures as per 23 May 2021:

- 4.9 million people downloaded the *CoronaMelder*, which corresponds to 28% of the population.
  - This number increased rapidly shortly after the launch in October and has leveled off since. No net decline had been reported so far.
  - The percentage of app users is roughly stable across age groups but increases with education level.
  - An estimated 2.9 million people (around 17% of the population) actually *use* the app.
- 174,000 infected people notified their contacts via the *CoronaMelder* (3.6% of the installed base).
- 189,000 people applied for a test after a notification in the app.
  - 77% of these had not or not yet been reached via manual contact tracing.
- 14,000 people tested positive after receiving a notification.

The evaluation by Ebbers at al. (2021) reaches the following conclusions:

- More than half of the people who applied for a test after a notification in the app were never notified by GGD. Without the app, this group would not have been identified, or only after they developed symptoms. Another group was notified by the app before they had been reached by traditional contact tracing enabling them to avoid further contacts and to apply for a test earlier.
- About 3-5% of people who applied for a test after a notification in the app but who did not have symptoms tested positive, as opposed to around 1% in the general population.
- Overall, around 1 out of 10 test applications and 1 out of 20 positive tests was triggered by the CoronaMelder. Between 26 September 2020 and 18 April 2021 this amounted to around 11,000 positive tests triggered by the app, while around 128,000 negative tests were triggered by the app.
- Modelling by RIVM indicates that the app prevented more than 15,000 infections and over 200 hospitalisations between December 2020 and March 2021 (based on 7,500 positive tests triggered by a notification).
- 97% of app users state they were willing to stay home upon such instruction by the app and 95% would take a test. In practice, these numbers were considerably lower: 45% of the people who received a notification actually stayed home, while 41% took a test.

Overall, the authors conclude that the app had a small but noticeable added value. They state that the fact that it is small is understandable, given the limitations to social life since the introduction of the app. This implies that as restrictions continue to be rolled back in the coming months, the added value of the *CoronaMelder* will be expected to increase. It might increase further if more people are convinced to use the app, if the time between contacts and notifications decreases, and if compliance with instructions upon notifications is improved.

Ebbers et al. (2021) also pay attention to the unintended effects of the app. App users might, for instance, feel overly safe, resulting in non-compliance with other measures. The authors find no indications for

756 Around 75% of positively tested app users indeed shared their key. This is likely an underestimation of the willingness to do so, since contact tracing employees do not always ask about the use of the *Coronamelder* (Ebbers et al. 2021, p. 19).

this and consider it unlikely. They do, however, find indications that some people feel public pressure to install and use the app.[757] Lastly, they mention the issue of false positives, for instance, when signals travel through walls.

The authors (p. 26-27) point out that international studies show that contact tracing apps can be more effective than manual contact tracing and can help reduce the reproduction rate R^0, the number of infections and the death toll. These insights are based on modelling rather than empirical studies, however.

8.3 Incentives for using digital contact tracing apps

Compliance with most measures mentioned in the introduction benefit individual and public health simultaneously, provided they are indeed effective in preventing the spread of the virus. For instance, by respecting social distancing rules, an individual reduces both the risk of contracting the virus, and the risk of infecting others. Vaccination has a similarly symmetric effect, benefitting both the person receiving the vaccination, and his or her future contacts.[758]

Digital contact tracing apps are fundamentally different in that respect. The app does not prevent the user from being infected. Therefore, under the assumption that early and often pre-symptomatic knowledge of a possible infection has no effect on treatment and recovery, there are *no personal health benefits for a user of the app*.

What the app does do is increase the likelihood of early detection of being infected and by doing so, enables a person to take action to prevent spreading the virus further. Therefore, installing the app is something one does for the health of others (or in response to social pressure to that end). Potential health benefits fall on the contacts a person would have had and via them to others whom they might have infected, while potential costs fall on the person installing the app. This is very comparable to the classic public good problem, in which people are unwilling to invest in public goods (non-rival and non-excludable goods) and prefer to free-ride instead.

Of course, the potentially positive health effects for contacts as well as for society at large can still be a valid incentive for a person to install the app. In economic terms: a person can derive utility from contributing to the health of their relatives and others and of 'being a good citizen'[759] (see also the empirical findings in section 9). On top of this, there is an indirect effect: that by doing so, one contributes to the re-opening of society, which also brings private benefits to most people. Indeed, a consumer survey indicates that 47% of the *CoronaMelder* users agree with the statement that using the app makes one a good citizen, opposed to 14% of people who stopped using the app and 9% of non-users (Ebbers at al. 2021, p. 53). A similar pattern is found for the statement that using the app helps the economy. Agreement levels with the statement that the app helps protect people with vulnerable health is substantially higher at 78% among users of the app. Interestingly, 34% of non-users and 41% of previous users also agree with the latter statement. This raises the question whether these groups consciously decide *not* to contribute to that protection, or fail to understand that such protection is provided when *others*, not just vulnerable groups, install the app. There are strong network externalities associated with installing the app: if more

757 This is in line with the monitoring framework (see chapter 9) which found that people do not feel pressure from the government or their employer to install the app, but many people – in particular younger age groups – often feel morally obliged to install the app.

758 Note, however, that the size of these effects in both directions may differ, depending on the age and overall vulnerability of a person. Young, healthy people have relatively little to fear from being infected compared to elderly people, whereas their disutility from social distancing is likely to be larger. This implies that the net individual incentive for complying with generic measures as well as the incentive for taking a vaccination is considerably smaller for younger age groups in good health – hence clandestine 'Corona parties'.

759 In the behavioural economic literature, this is referred to as the 'warm glow' of giving (coined by Andreoni, 1989).

people install the app, the chances increase that the contacts of an infected person will be detected.

Whereas these potential benefits of the app are primarily indirect, the potential costs fall on the user. So, what are the potential costs for the person installing the app? In monetary terms, the app is free. However, installing the app requires one to ‘spend’ a minute or so via a mobile connection, and spend a few MB of data credit, as well as storage space on the smartphone. Once installed, the app continues to use data to check periodically for possible infectious contacts and requires Bluetooth to remain active, which adds to battery depletion (despite the fact that the app uses ‘Low Energy Bluetooth’), possibly contributing to the nuisance of having to rechange at an inconvenient moment, on top of the actual energy costs of recharging.

These are all very minor disincentives for installing and using the app, but in the absence of private benefits, they might still contribute to the relatively low level of adoption seen in the previous section. What is more, these ‘costs’ appear to be overestimated by non-users: 22% of them think it would cost a lot of time and energy to install the app (opposed to 3% of users) and 49% of non-users expect the app to be user friendly (opposed to 99% of users) (Ebbers at al. 2021, p. 16-17). Overall, users of the app often see personal advantages (67%) and rarely disadvantages (7%), while non-users rarely see personal advantages (9%) and more often disadvantages (24%).

Privacy concerns are a more profound category of private ‘costs’ associated with installing the app. Survey results show that such concerns correlate strongly with app usage, while there are widely spread misconceptions of the privacy aspects of the app itself. Amongst app users, 85% believe personal information is kept strictly confident, while only 55% of non-users think so. Nevertheless 57% of app users think the apps records the user’s location; within the group of non-users, this is 68%. Remarkably, this misconception is more common among higher educated groups. Along the same lines, 35% of app users and 55% of non-users mistakenly think the app records their name and personal data.[760]

Reducing these misconceptions by providing better information will likely be helpful to improve the adoption rate of the app. However, to some extent, self-justification will play a role here: people who did not install the app for whatever reason soothe their consciences by stating it would be very complicated and time-consuming to do so. In such cases, providing better information would be of little help. Moreover, adoption rates comparable to that in the Netherlands have also been observed in other countries, such as Germany and Switzerland (Rehse and Tremöhlen 2020, p. 2, 38).

To conclude this section: the asymmetry between the costs and benefits of app usage remains a fundamental obstacle for large-scale voluntary adoption. It is the classic public good problem all over again. For that reason, it remains essential to reduce the actual and the perceived personal costs of using the app. Particularly in relation to privacy issues, misconceptions about how the app works could be reduced by providing better information, which will likely be helpful to improve the adoption rate of the app. From an economic perspective, even subsidizing app users to compensate them for the positive externalities of installing and using the app could be justified, although care should be taken not to damage intrinsic motivation in this way (see also: Rehse and Tremöhlen 2020, p. 24-27). One way to do this might be a lottery amongst active app users, like the State of Ohio did with people who were vaccinated, leading to a substantial increase in the vaccination rate.[761]

760 See also monitoring framework. See chapter 9.
761 See: https://odh.ohio.gov/wps/portal/gov/odh/media-center/odh-news-releases/odh-news-release-05-20-21.

8.4 Towards a social cost-benefit analysis

Now it is time to develop a more comprehensive economic perspective on the direct and indirect social costs and benefits of the *CoronaMelder* app. While a full social cost-benefit analysis (CBA) does not fall within the scope of this expert opinion, a few rudimentary steps have been taken in this section.

An important and non-trivial starting point for any such analysis is the counterfactual: what is the next best policy or course of action relative to which costs and benefits are assessed? As mentioned above, Ferretti et al. (2020) proposed digital contact tracing apps as an alternative to more restrictive measures. However, such a counterfactual statement would entail not only analysing the effects of the app in greater detail, but also those of the other measures at stake. It was also mentioned in the introduction that some people claim that for several of these generic measures, the costs outweigh the benefits. If that was the case, such counterfactuals would flatter the picture for contact tracing apps. Alternatively, the two CBAs mentioned in the introduction establish sound benefit-to-cost ratios for the generic package of restrictive measures in the US, which would imply an unnecessarily high benchmark for the app. Therefore, it is preferable either to look at the alternatives of 'more intensive manual contact tracing' or 'doing nothing'.

8.4.1 Costs and benefits relative to doing nothing

If 'doing nothing' is considered the next best course of action, one should start by taking stock of all the societal effects of the app. On the cost side of the balance sheet are the costs of developing and maintaining the app, and of the publicity campaign held to promote it. Based on information from the Health Ministry obtained by the project team in november 2020, these costs were €12.6 million (€5 million for development, €2.8 for communication, €3 for maintenance/operation, €1.8 for policy).[762]

Additional costs are the unintended effects as mentioned by Ebbers et al. (2021): the disutility of the public pressure some people feel and privacy concerns, as well as the energy and data consumption of installing and using the app. On top of that, false notifications lead to substantial time and costs wasted on testing and self-isolation.

Most of these effects are hard to quantify, let alone express in euros without extensive research. However, an effort can be made to tentatively estimate the social costs of the latter, assuming that all negative tests triggered solely by the app would not have taken place without it. As was mentioned in Section 2, this amounts to 128,000 tests between 26 September 2020 and 18 April 2021. So, what are the total social costs of a negative test?

First, there are the actual cost of the test itself including its analysis. Since no detailed information about the costs of official GGD-testing (and manual contract tracing) are available, rough estimates have to be made. Currently, commercial PCR tests are advertised in the Netherlands at prices from €75. Assuming a profit margin of 15% gives a cost estimate of €65 per PCR test. GGD testing may operate at lower costs, given the substantial economies of scale it benefits from.

Added to that are the time costs of taking the test and the inefficiencies/loss of utility from self-isolation until the negative result is available. For the purpose of this estimate, it is assumed here that on average a working day is lost in this way, valued at the average gross wages in the Netherlands, which was €24/hour in 2020.[763] Thus, the total welfare costs of a negative test prompted by the *CoronaMelder* will be in the

762 In a full-blown CBA, these costs figures warrant further scrutiny. For instance, there may be additional costs of the app at the end of the municipal health services (GGD). On the other hand, some of these costs directly lead to benefits for other economic actors, most notably the costs of advertising which consist largely of scarcity rents.

763 See: https://www.cbs.nl/nl-nl/visualisaties/dashboard-arbeidsmarkt/ontwikkeling-cao-lonen/uurloon. Again, this is a ballpark estimate. On the one hand, the average productivity of employees exceeds these gross wages, so if a full day's work is lost, the costs will be larger. On the other hand, the costs associated with those who are retired, going to school or not working for other reasons will be smaller.

order of 8×€24 + €65 = €257. The total costs of 128,000 such false alerts between 26 September 2020 and 18 April 2021 amounts to €33 million. The full costs of the app and testing due to false alerts combined add up to around €46 million. Including the costs of testing positive cases, these are around €48 million.

On the positive side are the welfare gains of preventing infections. Section 2 mentioned the estimate by RIVM that the app prevented more than 15,000 infections and over 200 hospitalisations between December 2020 and March 2021. Extrapolating this to September-April to compare the costs and benefits over the same time span would lead to the prevention of more than 22,000 infections and around 300 hospitalisations.[764]

An alternative way to arrive at an estimate for the number of prevented infections is via the 11,000 positive tests triggered by the app: Assume a reproduction rate R^0 which is constant over time at 0.9 (in fact, it has been larger than 1 for considerable periods between September 2020 and April 2021). And assume that an infected person notified by the app manages to halve this to 0.45, after which the chain of infection continues at the 'ordinary' reproduction rate of 0.9. Then each positive test triggered by the app prevents 0.45 × (1 + 0.9 + 0.92 + …) = 4.5 subsequent infections. At an R^0 of 0.8 this would add up to 2. Correspondingly, 11,000 positive tests triggered by the app would prevent a chain of around 22,000 to 50,000 subsequent infections. Following the ratio between infections and hospitalisations used by the RIVM, the number of prevented hospitalisations would lie between 300 and 680.

The mortality rate of COVID infections in a country depends significantly on the composition ofits population (age, the prevalence of obesity and diabetes). In a meta-analysis of several studies, Brazeau et al. (2020) estimate the mortality rate in high income countries (with a greater concentration of risk groups) to be 1.15% (0.78~1.79%). This is fairly close to the current ratio of 1.06% based on the official statistics for the Netherlands,[765] and at the high end of the bandwidth of 0.5~1.4% for the first wave in European countries, mentioned in a more recent CBS publication (Stoeldraijer et al. 2021). During the second half of the time span from September 2020 – April 2021, the vaccination programme started to gather steam (which started to protect vulnerable groups from the beginning of January); in the estimations below, a mortality rate of 0.5%, at the low end of these estimations, is used. This implies that between 110 and 250 deaths were prevented by the *CoronaMelder.*

So, how do the health benefits of the *CoronaMelder* compare to the estimated costs of the app and the social cost estimate of testing? Since the focus here is on the health benefits due to positive cases detected via the app, the costs of testing these cases should also be included, and a total cost estimate of €48 million is used. Simply looking at the infections prevented, these total costs range from €960 to €2,180 per infection; looking only at the deaths prevented, they are in the order of €190-440,000 per death prevented. At a value of €80,000 per healthy life year lost (Zorginstituut Nederland 2018), these costs per death prevented would equal an average of 2.4~5.5 healthy life years lost. At first sight, these numbers do not look unrealistic. Note that Doti (2021) used a much higher age-adjusted value of statistical life of $4.2 million and Broughel and Kotrous (2021) a value per life saved of around $1 million.

These numbers imply that the social costs associated with the *CoronaMelder* may be offset by the prevented lost value of statistical life, merely on the basis of prevented deaths. A more refined calculation of the expected life years saved by prevented deaths could make this even more precise. The additional social benefits in a more refined calculation would derive from prevented symptomatic short COVID cases with effects in the order of a few days' sick leave, prevented long COVID cases with serious losses in quality of life over several months, and the prevented costs of hospitalisation.

764 The RIVM estimate was based on 7.5 thousand positive tests triggered by the app, while during the period September-April, there were 11,000 such tests, i.e., 47% more.
765 17,695 deaths and 1.67 million infections as per 8 June 2021, both likely to suffer from underreporting.

8.4.2 Costs and benefits relative to manual contact tracing

Lastly, a brief comparison of costs and benefits is made relative to those of manual contact tracing. In Ebbers et al. (2021, p. 22), 1,377 test applications were attributed to manual contact tracing (following the same logic of which 139,000 tests are attributed to the *CoronaMelder).* A larger share of 18% or 226,000 of these tests turned out positive. Using the same estimate for the social costs per test as for the app (€257), this translates to a social cost of €354 million of testing triggered by manual contact tracing.

To complete the picture, an estimate of the costs of manual contact tracing is required. In a newspaper interview, GGD director Sjaak de Gouw estimated the time required for proper contact tracing at around 8 hours, but due to the high numbers of those infected, investing so much time is often not possible.[766] Assuming an average of 2 hours of contact tracing for each infection at an hourly cost of €24 including overheads, the cost of manual contact tracing for the 1.1 million infections in the period September 2020 – April 2021 would be in the order of €54 million. This would bring the full costs of manual contact tracing and the tests it triggered to around €410 million.

Per positive test that manual contact tracing triggers, this corresponds to €1,800. Note that this number is based on a very rough estimate for the number of hours invested in contact tracing and assumes these contacts would not apply for a test without contact tracing.

For the *CoronaMelder* app, this metric this is around €4,400 (11,000 positive tests triggered by the app, at a total social cost of around €48 million). Despite the fact that these numbers are necessarily based on many assumptions, some of which are rather crude, this suggests that the full social costs of detecting infections via the *CoronaMelder* app are higher than via manual contact tracing. This outcome does not so much depend on the costs of developing the app, but rather at the lower percentage of positive tests triggered by the app: 10.4% for the app, versus 18.1% for manual contact tracing. As a result, the social costs of negative tests outweigh the efficiency of the app.

8.5 Conclusions and discussion

This paper developed an economic perspective on the *CononaMelder*, the Dutch contact tracing app launched 10 October 2020 with the aim to assist or supplement public health institutions in tracing the recent contacts of someone testing positive for COVID-19, which may have led to new infections, and to slow down the spread of the virus by urging these contacts to be tested and quarantine until it was clear if they were also infected.

Analysing the incentives for using digital contact tracing apps, it is observed that there are *no personal health benefits for a user of the app*. The app increases the likelihood of early detection of being infected and by doing so, enables one to take action to avoid spreading the virus further. Thus, any potential health benefits fall on the contacts a person would have had (and via them to others), while any potential costs fall on the person installing the app.

This asymmetry remains a fundamental obstacle for large-scale voluntary adoption. Therefore, it remains essential to reduce the actual and the perceived personal costs of using the app to increase its adoption. Particularly in relation to privacy issues, misconceptions about how the app works could be reduced by providing better information. From an economic perspective, even subsidizing app users to compensate them for the positive externalities of installing and using the app could be justified. One way to do this would be a lottery amongst active app users, like the State of Ohio did amongst people who were vaccinated, leading to a substantial increase in the vaccination rate.

766 https://www.parool.nl/nederland/ggd-baas-over-contactonderzoek-liever-zelf-bellen-omdat-er-schaamte-is~b590d7cb/.

A tentative analysis of the social costs and benefits of the *CoronaMelder* app suggests the benefits balance the costs, even if only looking at life years saved by preventing Corona deaths. Additional social benefits in a more refined calculation would derive from prevented symptomatic short-term COVID cases with effects in the order of a few days' sick leave, prevented long-term COVID cases with serious losses in quality of life over several months, and the prevented costs of hospitalisation.

On top of this, future benefits of the app could be generated if the app contributes to the possibility of rolling back social distancing interventions and the re-opening of society. The latter will increase the number of contacts with people that a person who is positive does not know and therefore, cannot be notified privately or via manual contact tracing.

The accuracy of app notifications – the percentage of tests triggered by the app that turn out positive – is key to its positive contribution to social welfare. This percentage is considerably lower for the app than for tests triggered by manual contact tracing, which suggests it can be efficient as an addition to manual contact tracing, rather than as a substitute for it. This is further underscored by the relatively low adoption rate of the app.

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