De Økonomiske Råd
Formandskabet

CHAPTER V
EPIDEMIOLOGY AND ECONOMICS

Danish Economy, Autumn 2020

CHAPTER V
SUMMARY

The chapter examines the interrelationship between epidemiology and economics, and the trade-offs that society faces in the event of a virus outbreak. The chapter is based on the global outbreak of coronavirus in 2020, but the considerations are relevant for future virus outbreaks as well.

Various strategies to handle a virus outbreak are discussed, i.e. containment (where the objective is eradicating the virus before it is widely spread in society), suppression (where the purpose is reducing transmission) and mitigation (where the virus is allowed to spread widely in society but at a controlled rate). It is discussed under which circumstances the various strategies are beneficial.

Finally, the chapter discusses some central tools to achieve a given strategy and how to use them appropriately. These include partial lockdowns of the economy, contact tracing and testing.

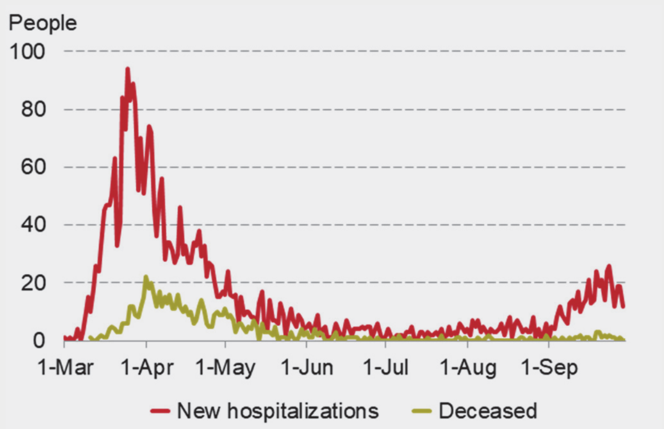
V.1 INTRODUCTION

Outbreak of COVID-19 in Denmark

Like most of the world, Denmark was hit hard by the outbreak of COVID-19 in early 2020. Within a few weeks a significant number of Danes became infected with the virus, and the number of new hospital admissions with COVID-19 reached almost 100 a day at the end of March, cf. Figure V.1. The spread of the infection also had the consequence that between 10 and 20 people with COVID-19 died every day at the end of March and the beginning of April.

FIGURE V.1 NEW HOSPITALIZATIONS AND DEATHS

The number of newly admitted to the hospitals with COVID-19 reached almost 100 per day in March 2020 but fell markedly thereafter. In September, it has increased to around 15 per day. The number of deceased per day with COVID-19 has dropped significantly since April.



Notes: The figure shows the daily number of newly hospitalized people with covid-19 and the daily number of people who died with COVID-19.

Source: www.ssi.dk.

A number of initiatives were aimed at limiting transmission

With the prospect of a marked increase in the number of infected people and with the risk of significant capacity pressure on the healthcare system, the government implemented a number of initiatives from mid-March that were aimed at limiting the spread of the virus. These included the closure of schools and childcare facilities as well as parts of the economy, imposition of travel restrictions and a ban on gatherings. A work-from-home order was also put in place for a large proportion of public sector employees. In addition, the authorities encouraged people to socially distance and ensure they practiced good hand hygiene.

Significant decline in new hospital admissions and deaths since April, but an increase in recent times

In early April the number of new hospital admissions began to fall sharply, and shortly afterwards the daily number of COVID-19 deaths followed. This trend continued in the following months despite the gradual easing of restrictions during May, including a partial reopening of some economic activities that had been locked down. Since early August, however, there has been a sharp increase in the number of people who have tested positive to COVID-19, and recently the number of new hospital admissions has started to increase.

The outbreak of the virus is not just a health crisis

The outbreak of COVID-19 has not only had health consequences. Both globally and in Denmark, there has been a marked decline in economic activity during 2020 and unemployment has risen. The decline in economic activity reflects several different factors, including that consumers and businesses have been reluctant to consume and invest, and that, as mentioned, certain parts of the economy have been in lockdown.

The chapter examines the interaction between viruses and the economy

This chapter examines the interaction between viruses and the economy and the associated policy trade-offs. The chapter is based on the outbreak of COVID-19 in 2020, but many of the issues discussed in the chapter would be also relevant if a new outbreak of another type of virus should occur in the future. The chapter presents various strategies for dealing with a viral outbreak, including containment (where the goal from the very beginning of the outbreak is to prevent the virus from being introduced into the community); suppression (where an attempt is made to limit the spread of infection so that it does not become widespread in the community); and mitigation (where the goal is a positive but controlled spread of infection in the community). The economic and epidemiological assumptions under which the various strategies are most appropriate are discussed. A strategy can be implemented by using a number of specific instruments, such as lockdowns, mass testing and contact tracing. The advantages and disadvantages of selected instruments are discussed, including how they can be used to reduce infection in the most cost-effective manner. The chapter does not contain an actual evaluation of the Danish authorities' strategy, nor does it include a forecast for the evolution in the number of people infected.

Content of the chapter

Section V.2 introduces some key epidemiological concepts and uses a basic epidemiological model to illustrate the spread of a virus in a society. Within the framework of this model, the consequences of measures that reduce the spread of infection over a period of time are also illustrated. Section V.3 focuses on the interaction between economic activity and epidemiology. The section first discusses how the outbreak of a virus can affect economic activity. Then the economic-epidemiological model of Eichenbaum et al. (2020a), which takes into account some of these channels, is used to illustrate the central trade-offs that the authorities face in the event of the outbreak of a virus. The model used is simplified in many ways, so the final part of the section discusses some other factors that are not included in the Eichenbaum et al. (2020a) model but which are relevant to the central trade-offs.

Section V.4 summarises the two preceding sections and discusses the circumstances in which different strategies to counter the outbreak of a virus may be appropriate when taking into account both the health and economic aspects. Given the choice of strategy, there are various specific instruments that may be suitable for implementing the strategy. Section V.5 discusses a number of these instruments, including how they can be implemented to reduce the spread of infection in the most cost-effective way. Finally, section V.6 concludes the chapter and contains the Chairmanship's recommendations.

V.2 SPREAD OF DISEASE IN A BASIC EPIDEMIOLOGICAL MODEL

Contents

This section introduces some key concepts, and subsequently uses a basic epidemiological model to analyse the effects of policy measures that reduce the spread of infection over a period of time. The model used in this section does not contain a description of economic behaviour or of how people in general respond to a viral outbreak. The section is only intended to illustrate the evolution of infection in a population and is, therefore, only a first step in understanding the interaction between epidemiology and economics. In section V.3 an economic-epidemiological model that builds on the model used in this section is presented.

VIRUS TRANSMISSION AND EPIDEMIOLOGICAL CONCEPTS

Viruses spread via susceptible and infected people coming into contact

In the event of a viral outbreak, a section of the population will be susceptible to infection. As a result of contact between people, some of the susceptible will become infected, after which they can pass the disease on to other susceptible people. Depending on the nature of the virus, some of those who are infected may die, while others will recover. The recovered people will often have developed antibodies to the virus in question, which may permanently, or for a period of time, reduce or completely eliminate their risk of re-infection.

Reproduction number

How contagious a virus is can be characterised by the so-called reproduction number, which indicates, on average, how many people an infected person manages to infect while infectious.

THE BASIC AND EFFECTIVE REPRODUCTION NUMBER

The basic reproduction number (also called R_0) indicates how many people an infected person infects, on average, during the period in which they are infectious, calculated in the hypothetical situation where the entire population is susceptible to the virus. As a starting point, the basic reproduction number is constant over time and reflects, among other things, how contagious the virus is. However, it can be affected by changes in the behaviour of the population, for example, it can change if there is a greater degree of compliance with hygiene advice, or if the population strictly complies with physical distancing guidelines.

The effective reproduction number indicates how many people an infected person infects, on average, given the number of people who are susceptible to the virus at that time. A large proportion of susceptible people will thus tend to increase the effective reproduction number because, all other else being equal, it will be more likely that an infected person will meet a person who is susceptible.

Herd immunity: The effective reproduction number falls below one

As long as the effective reproduction number is greater than one, the number of infected people will increase over time. To the extent that immunity is acquired by those who recover, the number of people susceptible to the virus will thus decrease over time. At some point, the number of susceptible people may have fallen to such a low level that the effective reproduction number falls below one, at which point there is "so much distance" between infected and susceptible people that it becomes difficult for the virus to spread. At this point, the community has reached so-called herd immunity, and the number of infected people will then begin to decline.[1]

HERD IMMUNITY

Herd immunity describes the situation where the number of people susceptible to the virus has decreased so much that the number of infected people begins to decrease over time. Herd immunity occurs when the effective reproduction number falls below one, so that, on average, 100 infected people manage to infect less than 100 susceptible people while they are contagious. Thus, the number of infected people will decrease over time as the infection intensity is not high enough for the virus to be maintained in the population.

The higher the basic reproduction number for a virus, the more the number of susceptible people must decrease before herd immunity is reached, cf. Box V.2 later in this section. This also means that a lasting change in the behaviour of the population that reduces the spread of infection has the consequence that it does not require such a large decrease in the number of susceptible people to achieve herd immunity.

A vaccine can contribute to herd immunity

Herd immunity does not necessarily have to be obtained as a result of a sufficiently large proportion of the population being infecting. If a vaccine against the virus in question is discovered, vaccination of a sufficiently large proportion of the population may also cause the proportion of the susceptible population to become so low that herd immunity is achieved.

1) In practice, the transmission of infection in the community can be significantly limited before herd immunity is achieved because not all infected people have an equal risk of spreading the infection. This can mean that the infection dies out for a period of time, even before herd immunity is reached, and then increases again at a later stage, for example as a result of so-called superspreader effects.

ILLUSTRATION OF THE SPREAD OF A VIRUS

SIR-model can illustrate the spread of a virus

A basic epidemiological model - a so-called SIR model[2] – that can be used to simulate the spread of disease is presented in the following. When extended below in section V.3 to include an economic model, the resulting so-called economic-epidemiological model can be used to study the interaction between epidemic dynamics and economic decisions and analyse the optimal policy response to a virus outbreak. The SIR model described below is quite stylised, but can illustrate some general features regarding the spread of infection.

Everyone is assumed to be equally susceptible and contagious

In the considered model, it is assumed that everyone who is infected at a given point in time has the same risk of infecting others. Thus, that there may be so-called super-spreaders who, for various reasons, manage to infect a large number of people is disregarded. The model is divided into periods: this is done in such a way here that each period corresponds to one week. The spread of the virus starts in the first week when a group of people become infected with the virus.

Three groups of people: Susceptible, infected and recovered

At any time, the population can be divided into three different groups of people:

- People susceptible to the virus (S)
- People currently infected with the virus (I)
- People who, after being infected, have recovered (R)

Some of the infected die and are no longer part of any of the three groups. The SIR model is formally described in Box V.1 below. In the following as well as in the section V.3 it is assumed that the recovered people have acquired ever-lasting immunity. A more general approach would take into account that immunity may be only temporary. Box V.4 later in this section presents some scenarios where immunity is only temporary.

Infection intensity depends, among other things, on how many people are susceptible

The intensity at which an infected individual infects others is determined, among other things, by how large a proportion of the population is susceptible to the virus at a given time. In addition, the intensity of infection is determined by factors such as the basic infectivity of the virus, the behaviour of the population (for example, in the form of physical distancing and hygiene) and the number and duration of contacts

2) SIR is an acronym formed from the words susceptible, infected and recovered. The framework of model considered here is close to the SIR model in Eichenbaum et al. (2020a), but the basic SIR model dates back to Kermack and McKendrick (1927).

the individual has (which can be influenced, for example, through policy measures). These other factors are taken as given in the model considered in this section.

Baseline scenario …

In the following, a stylised baseline scenario, in which 1 per 1,000 population is infected in week 0 as a result of external factors, is considered. It is assumed that the authorities do not impose any restrictions and that the population does not change its behaviour; people wash their hands and keep the same distance as before the outbreak of the virus and visit the same number of restaurants, museums and festivals etc.

… cannot be considered as a forecast

The baseline is adjusted such that the basic reproduction number is 2.1. Furthermore, it is assumed that 0.5 percent of infected individuals die.[3] These two parameters have been chosen so that they are consistent with the current knowledge about COVID-19, cf. Box V.1. It must be emphasised, however, that this is a stylised scenario and no attempt has been made to adapt it so that it reproduces, for example, the number of people who have been infected or died with COVID-19 up to now in Denmark. Therefore, the scenario illustrated here cannot be used to forecast the evolution of the virus in Denmark, nor can the model be used to evaluate the policy measures pursued. The model is also simplified in other ways. For example, capacity pressure on the healthcare system is not allowed for in the model; therefore, no account is taken of the consequences of a situation in which a large proportion of the population is infected with the virus at the same time leading to insufficient capacity in the hospitals, which presumably would result in increased mortality from the virus and from other diseases that also require treatment.[4]

In the baseline scenario, herd immunity is achieved after 18 weeks

In the baseline scenario without policy measures and behavioural changes in the population, herd immunity is achieved after approximately 18 weeks, cf. Figure V.2. At this point in time 52 percent of the population is, or have been, infected. This is the number required to obtain herd immunity with a basic reproduction number of 2.1, cf. Box V.2. After 18 weeks, the number of susceptible individuals has thus fallen so much that the effective reproduction number falls below 1, cf. Figure V.2.

3) For comparison, the mortality rate from ordinary influenza is around 0.1 percent.

4) Section V.3 considers a scenario in which it is assumed instead that the risk of death increases as the number of people currently infected increases.

BOX V.1 **THE SIR MODEL**

The following describes the SIR model used. t indicates the time calculated in number of weeks, with period 0 indicating the week in which the viral outbreak started. The population size at this time is given by N_0. A small part of the population, I_0, is infected with the virus, and the rest of the population $S_0 = N_0 - I_0$ is at this time susceptible to the virus.

It is assumed that the number of newly infected (i.e., entrants to the group of infected) from week 0 is given by:

$$Newly\ infected_t = \beta_t \cdot \frac{S_t \cdot I_t}{N_t}$$

This reflects that contracting the virus occurs as a result of the infected and the susceptible meeting. The parameter β_t captures the effect of various conditions, including government restrictions aimed at the business and private sectors as well as the behaviour of individuals, for example the degree of physical distancing between people and the adherence to advice regarding hygiene.

The number of infected people thus develops, week by week, as described by the following equation:

$$I_{t+1} = I_t + \beta_t \cdot \frac{S_t \cdot I_t}{N_t} - I_t \cdot (\pi_r + \pi_d).$$

Note that the number of infected people is a stock. A person can thus be in this group for a shorter or longer period of time. In each period there will be departures from the group consisting of the infected people who have recovered $(I_t \cdot \pi_r)$, and those who have died $(I_t \cdot \pi_d)$. The people who have neither recovered nor died in the current week remain in the group of infected people in the following week.

The number of susceptible people decreases as the virus spreads:

$$S_{t+1} = S_t - \beta_t \cdot \frac{S_t \cdot I_t}{N_t}$$

Thus, births and deaths that are unrelated to the virus in question are disregarded, and it is assumed that those who recover acquire life-long immunity. The number of recovered people is described by the following equation:

$$R_{t+1} = R_t + I_t \cdot \pi_r$$

The evolution of the total population is described by the following dynamic relationship:

$$N_{t+1} = N_t - I_t \cdot \pi_d,$$

BOX V.1 THE SIR MODEL, CONTINUED

Finally, the evolution in the number of deaths is described by:

$$D_{t+1} = D_t + I_t \cdot \pi_d$$

The parameter π_d is set such that 0.5 percent of infected people die. This is the same assumption as is used in Eichenbaum et al. (2020a), and it is based, among other things, on a South Korean study from March 2020. This study has the advantage that it is based on relatively extensive testing of the population, which provides a reliable estimate of how many people are actually infected. In a review study from August, the WHO finds that the risk of death for COVID-19 is between 0.5 percent and 1 percent, cf. WHO (2020b). In view of this, the assumption use here is at the lower end. On the basis of blood donor studies, Statens Serum Institut (2020b), on the other hand, estimate a mortality rate of 0.3 - 0.5 percent for COVID-19 and a recent study for Iceland finds a mortality rate of 0.3 percent, cf. Gudbjartsson et al. (2020).a) The risk of death will actually depend on a number of factors, including the age composition of the population, the proportion of the population who have chronic diseases and the quality of the healthcare system.

In the baseline scenario it is assumed that β_t is constant over time, and this is set at a level such that the basic reproduction number is 2.1. This corresponds to the Statens Serum Institut's assessment of the reproduction number for COVID-19 in Denmark for 12 March 2020, i.e., at the beginning of the coronavirus outbreak and before the effect of behavioural changes and lockdowns had affected this.b) Following Eichenbaum et al. (2020a), it is also assumed that an infection lasts for 18 days, and ends in either recovery or death. It is further assumed that an infected person is contagious throughout the period of illness.

In their evaluations of the consequences of easing restrictions in Denmark, Statens Serum Institut used more sophisticated versions of the model use here; so-called SEIR models (where "E" stands for exposed, i.e., the group of people who are infected but do not yet show symptoms), cf. Statens Serum Institut (2020a). This modelling includes, among other things, different age groups, as well as contact patterns in the population and hospital admissions.

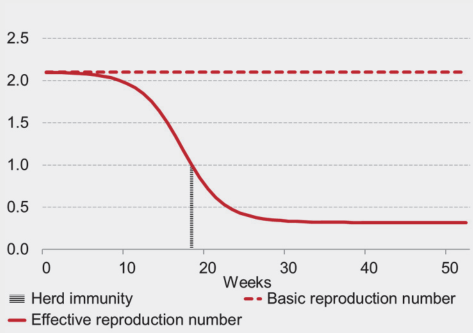
a) However, Statens Serum Institut (2020a), find that the mortality rate can be 0.9 percent if based on the representative testing performed by Testcenter Danmark.

b) See Statens Serum Institut: *Smittetryksberegning: Kommentar til debat om beregning af smittetryk*. May 19 2020, (in Danish). https://www.ssi.dk/aktuelt/nyheder/2020/05_smittetryksberegning_19052020.

FIGURE V.2 BASELINE SCENARIO

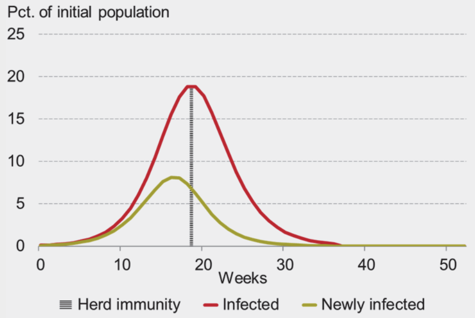
REPRODUCTION NUMBER

The effective reproduction number is 2.1 at the beginning of the outbreak, but decreases as the number of susceptibles falls.



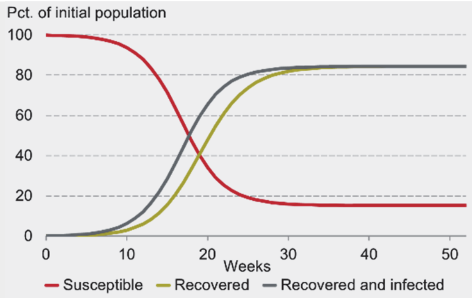
INFECTED

In the baseline scenario without public intervention, the number of currently infected reaches its peak level after 18 weeks, where 19 percent of the population is infected.



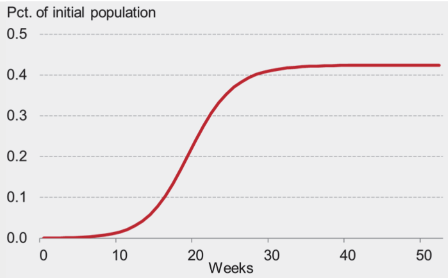
SUSCEPTIBLES AND RECOVERED

The number of people who have been previously infected with the virus reaches 84 percent of the population in the baseline scenario.



DECEASED

The number of deaths due to the virus reaches 0.42 percent of the population.



Notes: The assumptions underlying the baseline scenario are stated in box V.1. The figure in lower right corner shows the accumulated number of deaths.

Source: Own calculations.

This scenario can involve significant capacity pressure on the health care system

At the time herd immunity is achieved, 19 percent of the population is currently infected. In the baseline scenario presented here, no account is taken of the fact that such a scenario can lead to significant capacity pressure on the healthcare system, and that it can, for example, lead to a higher risk of dying from the virus or from other critical illnesses due to lack of available treatment. Nor has it been taken into account that people can change their behaviour to avoid becoming infected, which can help to limit the spread of infection and lead to a more protracted outbreak. This, in turn, is taken into account in the economic-epidemiological model used in section V.3.

The virus dies out by itself, …

In the scenario considered, the virus will actually die out after about 40 weeks as, by this time, the number of infected people is trivial. The fact that the virus dies out on its own, even in the absence of a vaccine, is due to the fact that a sufficiently large proportion of the population acquires immunity after being infected.

… but there is a significant degree of overshooting in the number of people who have been infected …

By the time the virus dies out 84 percent of the population will have been infected at some point. It is noteworthy that so many more people are infected than is required to obtain herd immunity. This effect is called overshooting. This can be seen as a result of the fact that, at the time that herd immunity is achieved, many people are infected, whereby a significant spread of infection continues to occur in the subsequent period. In the week just after the level of herd immunity is reached, a further 6 percent of the population will thus be infected, and more will be infected in the following weeks, until the spread of infection practically ceases after just over 30 weeks, cf. Figure V.2.

… and in the number of dead

Overshooting has, among other things, the implication that the final number of deaths exceeds the minimum number of deaths that follows from achieving herd immunity (in a situation without a vaccine). In the scenario considered (with a basic reproduction number of 2.1), this minimum number corresponds to 0.26 percent of the population.[5] In total, 0.42 percent of the population die over the entire outbreak, cf. Figure V.2.[6] The next section discusses how measures that affect the spread of infection can affect the degree of overshooting.

5) This is calculated as 0.5 percent (which is the mortality rate) of 52 percent of the population (which is the percentage of the population that needs to have been infected before herd immunity is achieved in the absence of a vaccine, cf. Box V.2).

6) However, as mentioned, the number of deaths can be significantly higher if the risk of death from the increased capacity pressure on the healthcare system is taken into account.

BOX V.2 **REPRODUCTION NUMBER AND HERD IMMUNITY**

In the framework of the model considered here, the effective reproduction number is given by:

$$\mathcal{R}_t = \beta_t \cdot \frac{S_t}{N_t} \cdot \frac{1}{\pi_r + \pi_d}, \tag{1}$$

where $\beta_t \cdot S_t / N_t$ indicates the intensity at which an infected person infects others, and $1/(\pi_r + \pi_d)$ is the expected duration of an infection. In the model, the basic reproduction number is:

$$\tilde{\mathcal{R}}_{0,t} = \beta_t \cdot \frac{1}{\pi_r + \pi_d}, \tag{2}$$

corresponding to (1) in the case where the whole population is susceptible to the virus (i.e., where $S_t/N_t = 1$), as is approximately the case at the beginning of the outbreak. From (1) and (2), the following relationship between the effective and the basic reproduction number is obtained:

$$\mathcal{R}_t = \tilde{\mathcal{R}}_{0,t} \cdot \frac{S_t}{N_t}. \tag{3}$$

Herd immunity is defined as being achieved when the number of currently infected people peaks and, thereby, begins to decline. The time at which herd immunity is reached can furthermore be characterised by the effective reproduction number dropping to 1. From (3) it can be seen that this applies when:

$$\left(\frac{S_t}{N_t}\right)^* = \frac{1}{\tilde{\mathcal{R}}_{0,t}}. \tag{4}$$

In this scenario without a vaccine, it is equivalent to obtaining herd immunity when the number of people who are, or have been, infected is given by:

$$\left(\frac{I_t + R_t}{N_t}\right)^* = 1 - \frac{1}{\tilde{\mathcal{R}}_{0,t}}. \tag{5}$$

For example, the baseline scenario considered in this section assumes that the basic reproduction number is 2.1. As a consequence, in the absence of a vaccine, it is necessary for 52 percent of the population to have been infected before herd immunity is achieved, cf. Table A. Coupled with the other assumptions made in the baseline scenario (including no policy measures or behavioural changes in the population), this occurs, as mentioned above, after 18 weeks.

If, instead, the basic reproduction number is 1.5, only a third of the population are required to have been infected before herd immunity is achieved. Coupled with the other assumptions in the baseline scenario, this occurs after 33 weeks, as the spread of infection takes place at a slower pace than in the baseline scenario. If the basic reproduction number is instead 2.7, 63 percent of the population has to have been infected and herd immunity occurs after 14 weeks.

BOX V.2 REPRODUCTION NUMBER AND HERD IMMUNITY, CONTINUED

TABLE A HERD IMMUNITY IN THE SIR MODEL WITHOUT POLICY MEASURES

	$\mathcal{R}_0$ = 1.5	$\mathcal{R}_0$ = 2.1	$\mathcal{R}_0$ = 2.7
Proportion susceptible at herd immunity	66.7%	47.6%	37.0%.
Proportion of the population that is, or has been, infected when herd immunity is achieved[a)]	33.3%	52.4%.	63.0%
Mortality rate by achieving herd immunity[b)]	0.17%	0.26%	0.31%
Time required to achieve herd immunity[c)]	33 weeks	18 weeks	14 weeks

a) Assumes there is no vaccine available. The first two rows thus add up to 100 percent. Note that the final number infected will exceed those shown in the second row due to overshooting.

b) Assumes there is no vaccine available. Calculated as the assumed mortality rate multiplied by the percentage of the population that is or has been infected when herd immunity is achieved.

c) Calculated under the other assumptions in the baseline scenario, including that the initial number of infected people is 1 per 1,000 population.

Source: Own calculations.

The results above assume, among other things, that everyone in the population is equally susceptible to infection and has the same risk of infecting others. In practice, it will be the case that some people are more susceptible than others, and that some people are more infectious and more likely to infect others as a result of greater social contact. This can have the consequence of a selective depletion of the group of susceptible people early in a virus outbreak, as the people who are most susceptible to the virus and have the greatest risk of infecting others are infected early. The average (basic) reproduction number for the remaining share of the susceptible population will, therefore, subsequently be relatively low. This can lead to herd immunity being achieved when significantly fewer people are, or have been, infected than shown in Table A, cf. Gomes et al. (2020) and Britton et al. (2020)

Lower basic reproduction number gives a more prolonged outbreak, but with fewer infected

In the baseline scenario shown, as mentioned, it is assumed that the basic reproduction number is 2.1. Box V.3 illustrates an alternative scenario, where this is instead 1.5. It demonstrates, for example, the consequences of people permanently changing their behaviour and, to a greater extent, complying with hygiene advice and maintaining a physical distance from other people, as well as the consequences of the authorities implementing an effective test and trace strategy. In the scenario with a lower reproduction number, the spread of infection is slower; therefore, it takes significantly longer for the virus to die out.

On the other hand, herd immunity is achieved with fewer infections, and over the course of the outbreak, only 60 percent of the population have been infected. In addition, there will be less pressure on the healthcare system than in the baseline scenario

BOX V.3 SCENARIO WITH LOWER BASIC REPRODUCTION NUMBER

The following examines a scenario where the basic reproduction number is 1.5, i.e., it is lower than in the baseline scenario shown in the main text.

The consequence of the lower reproduction number is that the spread of infection takes place at a significantly lower rate. Although this scenario only requires that a third of the population is or has been infected for herd immunity to be achieved, this only happens after 33 weeks, cf. Figure A. At that time, almost 7 percent of the population are currently infected, and the capacity pressure on the healthcare system will be significantly less than in the scenario with a basic reproduction number of 2.1.

In this scenario, the virus is only really eradicated after about 70 weeks. On the other hand, fewer people become infected with the virus than in the baseline scenario. In total, 60 percent of the population will eventually be infected with the virus; thus, there is a lower degree of overshooting than in the baseline scenario. The number of deaths reaches 0.3 percent of the population over the whole period of the outbreak of the virus., cf. Figure B. This is thus also significantly lower than in the baseline scenario.

FIGURE A INFECTED

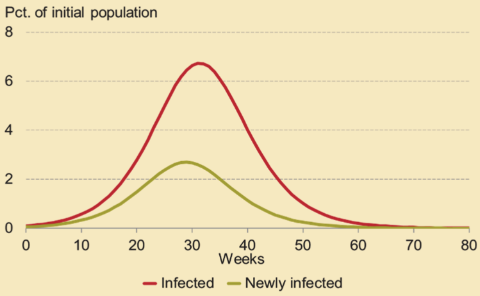
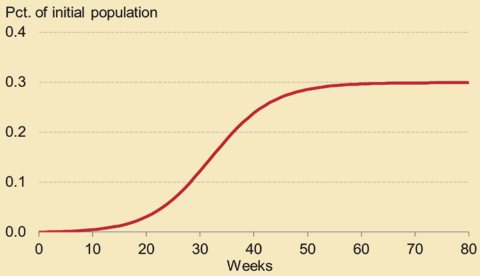


FIGURE B DECEASED



Notes.: The assumptions are the same as in the baseline scenario with the exception that the basic reproduction number is calibrated to 1.5 here.

Source: Own calcluations.

Temporary immunity can lead to waves of infection and more deaths

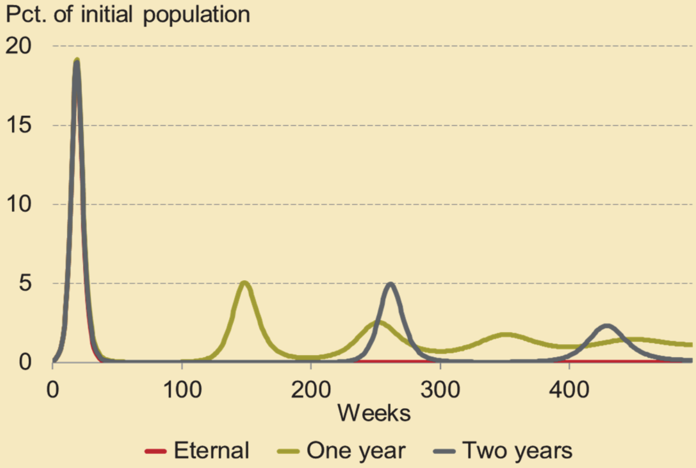
In all the scenarios considered in both this section and section V.3, it is assumed that those that recover have life-long immunity because they have formed antibodies to the virus. However, for COVID-19, for example, it is not certain that this is a valid assumption. Box V.4 illustrates some alternative scenarios, where, instead, it is assumed that people who have been infected are only immune to the virus for one or two years after they have recovered. As a consequence, over time there will be repeated waves of infection, where the number of infected people increases and then decreases. Temporary immunity also has the consequence that the number of deaths increases.

BOX V.4 TEMPORARY IMMUNITY

In the scenarios presented in both sections V.2 and V.3, it is assumed that those who have recovered acquire life-long immunity to the virus in question. This box considers two cases where a recovered person is only immune for one and two years (on average) after recovery, again assuming that no vaccine is discovered. Each week a certain percentage of those who have recovered will transition to being part of the group of people who are susceptible to the virus.

Temporary immunity has the consequence that recurrent waves will occur in the number of infected people. Thus, there will be periods when the number infected declines and periods where the number infected increases. The virus will thus never completely die out, but, over time, the fluctuations will diminish, cf. Figure A.

FIGURE A INFECTED



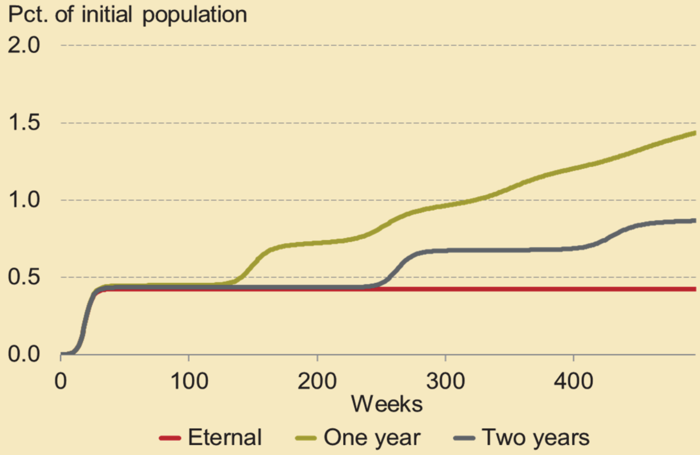
Notes.: In the figure "Eternal“ indicates the situation where an infected person gains immunity forever as in the baseline scenario in the main text. "One year“ denotes the scenario in which an infected person gains immunity for a year (on average) while "Two years“ correspondingly denotes the situation in which an infected person gains immunity for two years (on average).

Source: Own calculations.

BOX V.4 **TEMPORARY IMMUNITY, CONTINUED**

Temporary immunity will also have the consequence that the number of deaths due to the virus increases relative to the baseline scenario and that it grows over time. If, for example, those who have recovered are immune for one year on average, the number of deaths after ten years will be around 1.5 percent of the population (compared with 0.4 percent with lasting immunity).

FIGURE B **DECEASED**



Notes.: See notes to figure A.

Source: Own calculations.

THE CONSEQUENCES OF POLICY INTERVENTIONS

To what extent can overshooting be reduced?

As mentioned above, in the baseline scenario there is a high degree of overshooting. In other words, a larger proportion of the population has been infected than is necessary to obtain herd immunity (in the absence of a vaccine). In the following, within the framework of the model with lasting immunity, whether policy interventions that affect the spread of infection for a period can affect the degree of overshooting is examined. The section focuses only on the consequences of the given reductions in the spread of infection without indicating what kind of intervention has been implemented.[7] Three scenarios are considered:

- The measures reduce infection intensity significantly for a shorter period
- The measures reduce the intensity of infection for a longer period
- The measures gradually reduce the intensity of infection over the period in which the number infected increases, and are then phased out gradually.[8]

Short-term measures do not reduce the number of deaths

Figure V.3 shows the consequences of measures that reduce the basic reproduction number by 40 percent and 80 percent for a shorter period of 10 weeks starting from the third week. Such measures do not in themselves lead to a reduction in the degree of overshooting or the number of deaths in the long term, cf. the lower part of Figure V.3. This is because the situation is basically the same when the measures are removed as before they were introduced.[9] By severely limiting the spread of infection for a short period of time, there will be a very low degree of immunity in the population when the measures are removed.

7) The scenarios considered maybe the result of a temporary shutdown of parts of the economy, but they may also cover, for example, restrictions on freedom of assembly, travel restrictions or changed behaviour in the population, such as increased physical distancing, compliance with hygiene advice, etc.

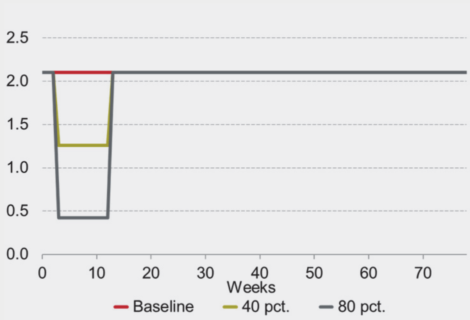
8) This type of intervention is interesting because, among other things, within the framework of the economic-epidemiological model used in section V.3, it can be considered optimal in some of the scenarios shown, in the sense that the welfare of society is maximised.

9) Unless the virus has been completely eradicated.

FIGURE V.3 MEASURES THAT ARE ONLY IN EFFECT BRIEFLY

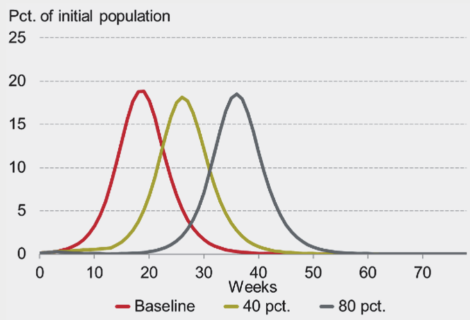
BASIC REPRODUCTION NUMBER

Measures that briefly reduce the number of newly infected …



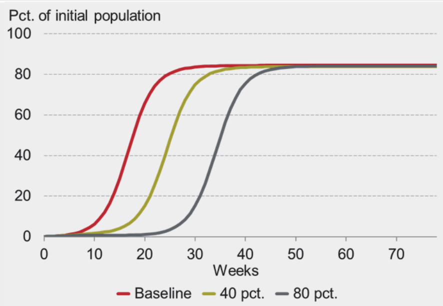
INFECTED

… postpone the time when the number of infected peaks, but do not significantly reduce the peak level.



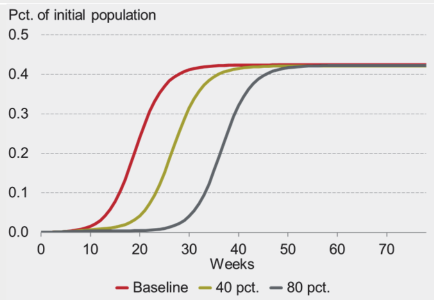
INFECTED AND RECOVERED

Measures that briefly reduce the number of newly infected will not in the long run reduce the number of people who have been infected …



DECEASED

… and thus do not reduce the number of deceased in the long run.



Notes: In the figures "40 pct." denotes a scenario, where the basic reproduction number is reduced by 40 percent from week 3 to week 13, cf. the figure in the top left corner. Correspondingly, "80 pct." denotes a scenario, where the basic reproduction number is reduced by 80 percent from week 3 to week 13. Notice that the three curves in the figure in the top right corner do not peak at the exact same level. However, the differences are small.

Source: Own calculations.

But short-term measures postpone the peak in the number of infected people

Furthermore, the short-term measures will not significantly reduce the number of infected people or the pressure on the healthcare system at the time when this is at its highest. On the other hand, they will both lead to this capacity pressure being reached at a later date. In the baseline scenario, the number of infected people peaks after 18 weeks, while this occurs after 26 weeks in the case of a temporary reduction in the reproduction number by 40 percent. In the case of a temporary reduction of the reproduction number by 80 percent, the number infected reaches its peak after 36 weeks. Thus, measures that temporarily limit the spread of infection will win time that can be used for capacity building in healthcare and infrastructure related to testing and contact tracing, as well as more time to research vaccines and effective treatments.

Measures that limit infection over a long period of time reduce the number of deaths, …

Figure V.4 shows the consequences of an initiative that, as in the green curve above, reduces the basic reproduction number by 40 percent, but over a period of one and a half years. Such an initiative would mean a marked (lasting) reduction in the number of deaths due to the virus. This reflects that such measures lead to a lower degree of overshooting in the number infected. Thus, over the course of this scenario, 64 percent of the population will have been infected, compared with 84 percent in the baseline scenario without policy interventions.

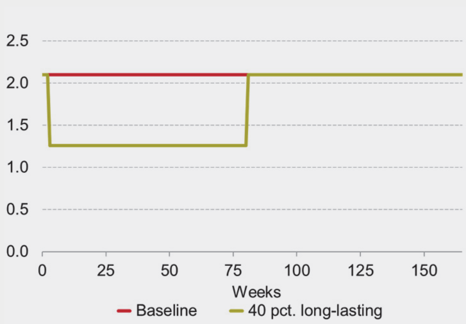
… because immunity builds up gradually and at a slower pace

This is because the spread of infection is impeded for a longer period, while at the same time a certain degree of immunity is built up in the population (as the spread of infection is ongoing, albeit at a lower level than in the baseline scenario). When the measures are lifted, there will again be a new increase in the number of infected people, but this will be of a limited size, cf. Figure V.4. There will thus be significantly less pressure on the healthcare system than is the case in the baseline scenario. (Thus, at no time does the number infected exceed 3 percent of the population.)

FIGURE V.4 LONG-LASTING MEASURES

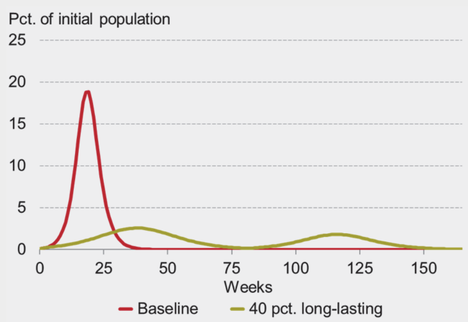
BASIC REPRODUCTION NUMBER

Measures that reduce the number of newly infected for a while (a year and a half) …



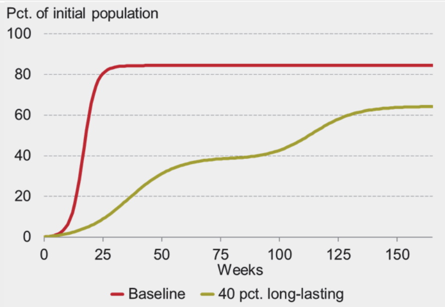
INFECTED

… can reduce the level at which the number of infected peaks markedly. This eases the pressure on the healthcare system.



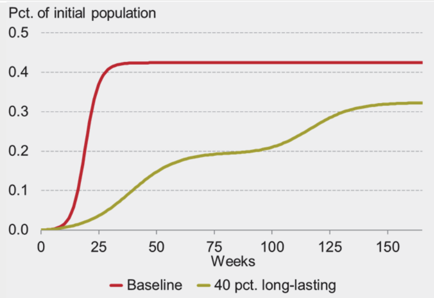
INFECTED AND RECOVERED

Measures that reduce the number of newly infected for a while (a year and a half) can reduce the degree of *overshooting* in the number of people who have been infected. …



DECEASED

… and thereby also reduce the number of deceased.



Notes: In the figures "40 pct. long-lasting" denotes a scenario, where the basic reproduction number is reduced by 40 percent for a year and a half starting from week 3, cf. the figure in the top left corner.
Source: Own calculations.

Gradual measures can be designed to reduce overshooting …

Finally, figure V.5 shows the consequences of measures that cause the basic reproduction number to gradually decrease as the number of infected people increases, after which the measures are gradually phased out as the number of infected people decreases. In the example considered, these measures have the consequence that the basic reproduction number decreases from 2.1 at the beginning of the outbreak to 1.5 after approximately 20 weeks, after which it again rises to 2.1 around week 40 and remains at this level, cf. Figure V.5. The gradual phasing out ensures that the effective reproduction number is kept below one after week 20. While in the baseline scenario, as mentioned earlier, it is necessary for just over 50 percent of the population to have become infected before the number of infected people begins to decline, in the scenario with gradual measures, only about one third of the population have to have been infected before the number of infected people begins to decline. This reflects that at the time the number of active cases peaks, the basic reproduction number has dropped to 1.5.[10] When the phasing out of the measures is under way, for example, in the form of the gradual reopening of industries that have been in lockdown, it happens so gradually that a new increase in the number of infected people is avoided. This reflects that the effective reproduction number, as mentioned above, is below one throughout the phase-out period. When, for example, the basic reproduction number is 2.1 after just over 40 weeks, the number of people who are or have been infected will amount to around 70 percent of the population, cf. the graph at the bottom left in figure V.5. This is thus higher than the level that ensures herd immunity with a basic reproduction number of 2.1 (i.e., 52 percent); therefore, there is no subsequent increase in the number of infected people.[11] The gradual phasing in and subsequent phasing out thus reduces the degree of overshooting.[12]

… and, thus, also the number of deaths

Overall, this has the consequence that the number of people who have been infected at some point before the virus dies out is reduced from 84 percent of the population in the baseline scenario to approximately 70 percent. This also means that the number of deaths is reduced from 0.42 percent of the population in the baseline scenario to 0.35 percent, cf. Figure V.5. The pressure on the healthcare system is also significantly reduced.

10) A lower basic reproduction number thus means that, all else being equal, herd immunity is achieved with a lower number of infected people, cf. Box V.2.

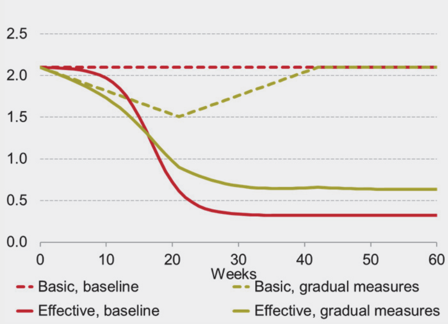
11) More generally, the measure considered ensures that the proportion of the population that is or has been infected throughout the whole phasing-out period exceeds the level needed to achieve herd immunity, given the current level of the basic reproduction number.

12) One can, of course, well imagine a more fine-tuned scenario in which the degree of overshooting is reduced even more than in the scenarios considered here.

FIGURE V.5 MEASURES THAT ARE IMPLEMENTED AND REMOVED GRADUALLY

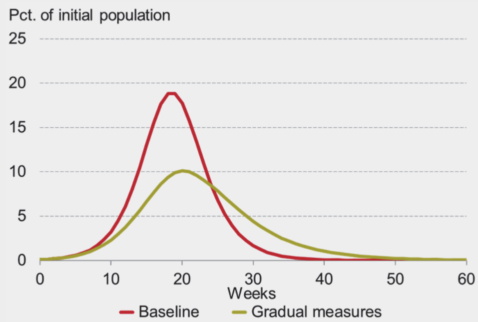
REPRODUCTION NUMBER

A scenario is considered where public measures result in the basic reproduction number decreasing while the number of infected increases.



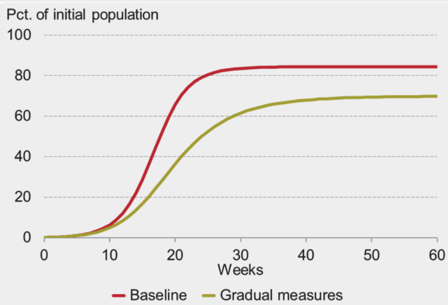
INFECTED

With the considered gradual measures, the number of infected peaks at 10 percent of the population which is much lower than in the baseline.



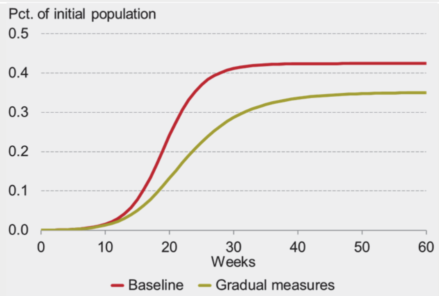
INFECTED AND RECOVERED

With the considered gradual measures fewer people will get infected in the long run ……



DECEASED

… and fewer will die.



Notes: In the figures "Gradual measures" denotes a scenario where the basic reproduction number is reduced while the number of infected increases and increased afterwards as the number of infected falls, cf. the figure in the top right corner. "Basic, baseline" denotes the basic reproduction number in the baseline scenario, "Effective, baseline" denotes the effective reproduction number in the baseline etc.:

Source: Own calculations.

SUMMARY

Summary

In this section the spread of a virus in a community is illustrated within the framework of a basic SIR model. In the scenarios presented, it is assumed that there will be no vaccine against the virus and that it is not possible to completely eradicate the virus via infection control measures. Therefore, the virus is only eradicated as a consequence of sufficient immunity being achieved in the population when many people have had the virus. In the scenario without any policy measures or behavioural changes in the population, at the time that the number of people infected peaks, there can be enormous pressure on the resources in the healthcare system. Furthermore, the number of people who have been infected at some point during the outbreak will exceed the number needed to achieve herd immunity. This so-called overshooting means that the total number of deaths is higher than the minimum number of deaths that follows from achieving herd immunity (in a situation without a vaccine and with a given mortality rate).

In the SIR model considered, measures that only have a short-term effect on the spread of infection in the community will not directly reduce the degree of overshooting. However, they can postpone the time that the capacity pressure on the healthcare system arises and, thus, give time for capacity building. Measures that reduce the spread of infection over a long period of time can, in turn, both reduce the degree of overshooting and significantly reduce the pressure on the healthcare system. These may, for example, be measures that are introduced gradually as the number of infected people increases and that are correspondingly phased out gradually afterwards.

V.3 THE INTERACTION BETWEEN VIRUS OUTBREAK AND ECONOMIC ACTIVITY

Contents

This section first discusses various channels through which a virus outbreak can affect the decisions of households and firms. Next, the model in Eichenbaum et al. (2020a) is used to examine the interaction between a viral outbreak and economic activity. Within the framework of this model, the basic trade-offs that the authorities face in the event of the outbreak of a virus are examined.

The literature on the interaction between economics and epidemiology is still in its early stages, and the model in Eichenbaum et al. (2020a) used in this section is simplified in many aspects. The last part of the section discusses some of the elements that have not been taken into account in the model, but which have consequences for the main trade-offs that the authorities face in the event of a viral outbreak.

EFFECTS ON ECONOMIC BEHAVIOUR

The outbreak of a virus can affect the behaviour of households and businesses through a number of channels, even when the authorities do not impose any restrictions.

Viral outbreaks can cause households to lower their consumption …

Households can respond to the outbreak of a virus by lowering their consumption to reduce the risk of becoming infected through consumption activities. Many consumer activities cannot be carried out without people coming into contact with others in shops, restaurants, the hairdresser, etc. A study focusing on the decline in consumption in Denmark and Sweden in the first months of the outbreak of coronavirus, for example, concludes that the virus outbreak itself contributed to a significant decline in consumption and that the closure of parts of the economy made only a small contribution to the economic decline, cf. Andersen et al. (2020) and box V.5.

… and change the composition of their consumption

However, some consumption activities involve a relatively low risk of contracting the virus, and the outbreak of a virus can thus cause households to turn their consumption towards activities with a lower risk of infection. Households can, for example, choose to cut back on restaurant and cinema visits and, to a greater extent, cook or buy take-away food and stream movies from home. Likewise, a viral outbreak can lead to people making more use of online shopping rather than shopping in physical stores.

BOX V.5 STUDIES OF BEHAVIOURAL RESPONSES TO CORONAVIRUS

A number of studies have focused on the consequences for economic behaviour of the COVID-19 outbreak.

For example, Andersen et al. (2020) use the difference in the extent of the shutdown of economic activity between Sweden and Denmark to examine how much the virus outbreak itself led to lower consumption and how much the lockdown contributed to this. In the study it is found that the decline in consumption was only slightly greater in Denmark than in Sweden (29 percent compared with 25 percent). This suggests that the majority of the decrease in consumption can be attributed to the virus outbreak itself. The study also finds that it is especially the elderly who reduced consumption, which is consistent with the fact that they are the group that is the most vulnerable to serious consequences from contracting COVID-19.

Chetty et al. (2020), based on data for the USA, analyse the effects of both the outbreak of COVID-19 and the subsequent policy response on the economy. The study finds, among other things, that, at the beginning of the pandemic, people significantly reduced their spending in areas with high infection rates and in sectors that require physical interaction.

On the basis of GPS data, Engle et al. (2020), examine the extent to which infection rates affect the mobility of the population in the USA. The study finds that an increased number of infections in a geographical area reduces the mobility of people, also when taking into account whether a curfew was in force in the areas in question. Curfews also reduce people's mobility. The study further finds that the effects of both infections and curfews are greater the higher is the population density of an area.

Virus outbreaks can reduce labour supply and lead to more work from home

A virus outbreak can also cause households to adjust their labour supply: people can choose to work fewer hours, take more holidays or a sabbatical to avoid being infected at work or on public transport to and from work. For those who have the possibility to work from home, it can also lead to more people doing so.

Virus outbreaks can lead to restructuring of production

A virus outbreak can also affect the decisions of businesses. This can, for example, have the consequence that enterprises shut down parts of their production or change the workflows for a period so that physical contact between employees and customers is avoided to a greater extent. If the virus outbreak leads to greater uncertainty or expectations of lower future earnings, it can also lead to a reduction in the volume of business investment.

In the following, an economic-epidemiological model is presented that takes into account two of the channels mentioned: households' consumption and labour supply decisions.

THE CENTRAL TRADE-OFFS PRESENTED IN AN ECONOMIC-EPIDEMIOLOGICAL MODEL

Interaction between the virus and economic behaviour

The model of Eichenbaum et al. (2020a) is used in the following to analyse the interaction between an epidemic and economic behaviour as well as the basic trade-offs that the authorities face. The model is based on the SIR epidemiological model outlined in section V.2, and it is still assumed, for example, that people who have been infected gain life-long immunity to the virus. The assumptions underlying the economic-epidemiological model are described in more detail in Box V.6.

The model is stylised

Both in terms of the epidemiological and economic assumptions, this is a highly stylised and simplified model. For example, it is assumed that individuals act solely for their own benefit and disregard the fact that they can infect others through their actions. In practice, it is conceivable that people's behaviour is motivated by consideration for both their own and others' well-being. In the model, moreover, it is only possible for the authorities to reduce the spread of infection by general restrictions on economic activity. The fact that it may be possible to limit the spread of infection through softer and more selective measures, such as the mandating mask wearing on public transport, testing and quarantining measures aimed at infected people, etc., is, therefore, disregarded. The model also ignores the fact that there may be significant differences in infectivity and mortality from viruses across population groups, just as it is assumed that there are no lasting consequences associated with being infected.

The exact orders of magnitude should not be taken too literally

As it is a highly stylised model, its results must be interpreted accordingly. While the model helps to illustrate some basic qualitative trade-offs that are relevant to the authorities' response to the outbreak of a virus, the precise orders of magnitude of the effects should not be overemphasised.

BOX V.6 THE ECONOMIC-EPIDEMIOLOGICAL MODEL

The model in Eichenbaum et al. (2020a) uses a simple SIR model with lasting immunity, like that outlined in V.2, which they extend to include a standard economic model to analyse the effects of households' consumption and labour supply decisions on the spread of the infection.

The total number of newly infected people is given by:

$$Newly\ infected_t = \pi_1 \cdot S_t \cdot C_t^S \cdot I_t \cdot C_t^I + \pi_2 \cdot S_t \cdot H_t^S \cdot I_t \cdot H_t^I + \pi_3 \cdot S_t \cdot I_t, \quad (1)$$

where C_t^S and H_t^S are, respectively, total consumption and hours worked for the group of people who are susceptible, while C_t^I and H_t^I are, respectively, total consumption and hours worked of the group of people who are infected.

Therefore, the term $\pi_1 \cdot S_t \cdot C_t^S \cdot I_t \cdot C_t^I$ is the part of the spread of infection that is due to human contact in connection with consumption activities, while $\pi_2 \cdot S_t \cdot H_t^S \cdot I_t \cdot H_t^I$ is the part of the spread of infection that is due to human contact in connection with work. Finally, $\pi_3 \cdot S_t \cdot I_t$ is the part of the spread of infection that is not a result of interactions connected to economic activity. By defining:

$$\beta_t = \pi_1 \cdot C_t^S \cdot C_t^I + \pi_2 \cdot H_t^S \cdot H_t^I + \pi_3, \quad (2)$$

equation (1) can be written as:

$$Newly\ infected_t = \beta_t \cdot S_t \cdot I_t. \quad (3)$$

This shows that the epidemiological part of the Eichenbaum et al.'s (2020a) model is just the SIR model used in section V.2.[a)] As can be seen from equation (2), β_t and, thus, the basic reproduction number is explicitly dependent on the economic decisions of households in the model used in this section.

The present model also takes into account that a vaccine against a virus is likely to be discovered. It is simply assumed that the number of future new infections is zero from the time the vaccine is discovered. The probability of such a vaccine being developed is assumed to be constant over time. Note that those people who are already infected at the time a vaccine is discovered do not benefit from the vaccine. It is also taken into account that an effective medical treatment may be discovered that cures those who are infected. Thus, it is assumed that there is no risk of dying from the virus from the time the effective medical treatment becomes available.

a) There is one difference in that Eichenbaum et al. (2020a) do not divide by the total population in the expression for total newly infected. However, this has very limited quantitative significance as, after all, relatively few people die as a result of the virus in the scenario considered here.

BOX V.6 **THE ECONOMIC-EPIDEMIOLOGICALTHE, CONTINUED**

The individual household is assumed to have an infinite planning horizon and at all times chooses consumption and working hours by maximising an intertemporal utility function given by:

$$U_0 = E_0 \sum_{t=0}^{\infty} \delta^t \left(k + lnc_t - \frac{\theta}{2} \cdot (h_t)^2\right), \quad (4)$$

where E_0 is the expectation formed at time $t = 0$, c_t og h_t are the consumption and labour supply decisions of the individual, δ is a measure of the extent to which households value consumption in the future relative to today, k is a constant and θ is an expression of how great a loss of utility households suffer by working rather than consuming leisure. The parameter k determines the level of utility each person obtains (independently of consumption and leisure) as long as she is alive. Thus k determines the social welfare loss of an additional death.

In the model, savings are disregarded; therefore, the individual's consumption in each period corresponds to their earned income after tax:

$$(1 + \mu_t) \cdot c_t = w_t \cdot h_t + T_t, \quad (5)$$

where μ_t is a time-varying tax on consumption, w_t is the individual's hourly wage and T_t is public transfer income. In the model, the parameter μ_t can be used to influence consumption and the labour supply decision, and can, therefore, be an instrument for, e.g., implementing a partial lockdown of the economy. It is assumed to be the only instrument available to the authorities to influence the spread of infection.

The individual household is free to choose its consumption and its working hours, taking into account equation (5). In their choice of labour supply, those who are susceptible to the virus take into account that an increased level of consumption and longer working hours increase the risk of contracting the virus. The infected and the recovered do not have a risk of reinfection. People infected with the virus have lower productivity and thus a lower hourly wage than they would otherwise have had, and for that reason, they work less.

Discovery of a vaccine and medical treatment is possible

The scenario considered takes into account the possibility that a vaccine against the virus and an effective medical treatment could be discovered. It is simply assumed that there will be no new infections from the time a vaccine is available.[13] ,[14] Similarly, it is assumed that there is no longer a risk of the infected person dying of the virus from the time an effective medical treatment is available. As in Eichenbaum et al. (2020a), it is assumed that in each period there is a constant probability that a vaccine will be discovered as well as a constant probability that a completely effective treatment will become available. These probabilities have been setup in the model such that, at any given time, it is expected that it will be a year before a vaccine is discovered and likewise for an effective treatment.

The susceptible reduce their consumption and labour supply

In the model, susceptible people can contract the virus in three ways: in connection with consumption activities, in the workplace and as a result of random contacts that are not related to work or consumption. In this section the spread of infection occurs systematically in connection with work and consumption. Individual households take into account the link between their own behaviour and the risk of contracting the virus. In the hope of avoiding being infected, the people who are susceptible to the virus (which at the beginning of the outbreak of the virus is by and large everyone) will, therefore, respond by reducing their consumption and labour supply as the number of people infected increases. This is consistent with the results of Andersen et al. (2020), which indicate that the outbreak of coronavirus itself led to a significant decrease in consumption, cf. Box V.5.

The infected and recovered behave as in the absence of the virus

In the model, the people infected with the virus behave in the same way as they would in the absence of the virus.[15] This is a consequence of the fact that, as mentioned, it is assumed that people behave selfishly, in that, in their behaviour decisions, infected people do not take into account that they can potentially infect others. People who have been infected and subsequently have recovered also act in the same way as they would have done in the absence of a virus outbreak, as it is assumed, as mentioned, that they have acquired life-long immunity

13) This is, of course, a highly simplistic assumption. There may be a period when it will be impossible to offer everyone a vaccine due to capacity issues. In addition, there may also be groups in the community who do not want to be vaccinated.

14) However, in this case there may be a group of people who are already infected and these will not benefit from the vaccine.

15) However, those infected have lower productivity and hourly wages and, as a result, choose to reduce the number of hours they work. This can also be interpreted as meaning that a proportion of those infected (20 percent over the course of the outbreak considered) cannot go to work as a result of illness, while the remaining proportion continue to work as before.

against the virus in question. Thus, for the recovered, there is no cost, in terms of risk of infection, of participating in economic activities.

Baseline with slightly fewer infected than in the SIR model

Box V.7 presents a baseline scenario based on the economic-epidemiological model used here, which builds on the basic SIR epidemiological model outlined in section V.2. The model assumes a basic reproduction number of 2.1 at the beginning of the outbreak. In the present baseline scenario, as mentioned above, in order to try to avoid becoming infected, those who are susceptible to the virus will reduce their consumption and labour supply as the number of infected people increases. In the baseline scenario, the reduction in consumption and labour supply leads to a decline in the basic reproduction number over the period during which the number of infected people increases. Thus, the change in household behaviour contributes to limiting the spread of infection during this period and, overall, the degree of overshooting and the number of deaths are reduced slightly compared with the results obtained from epidemiological-only models, such as the SIR model.

Negative infection externality

In the model considered, there is a negative externality associated with the behaviour of the infected people, who, as mentioned above, by assumption, do not take account of their risk of infecting people who are susceptible to the virus through consumption and work. Infected people will thus choose to consume and work more than is optimal from a social point of view.[16] Thus, measures that reduce activity in society for a period of time, and thus reduce the spread of infection and the number of deaths, have benefits for society.

16) In addition, there may also be an indirect externality. The people who are susceptible to the virus will, in their choice of behaviour, take into account the costs that they themselves will bear in the event that they become infected, but not the negative externalities they, as infected people, would be able to inflict on others. This has the consequence that susceptible people do not reduce their activity to a sufficient extent from a social perspective, cf. the results in Bethune and Korinek (2020).

BOX V.7 **THE BASELINE SCENARIO**

In the following, using the model in Eichenbaum et al. (2020a), a baseline scenario without policy interventions is presented. The baseline scenario builds on the basic SIR epidemiological model outlined in V.2 and assumes that:

- The basic reproduction number is 2.1 at the beginning of the outbreak
- The mortality rate of the virus is 0.5 percent
- Duration of the viral infection is 18 days

In addition, the same assumptions are used as in Eichenbaum et al. (2020a), including that:

- The probability of a vaccine being discovered is the same in each period,
- The probability of an effective treatment being discovered is the same in each period, and corresponds to expected discovery of a vaccine after a one year
- Activities related to consumption and work account for 2/3 of the transmissions of the virus at the beginning of the outbreak[a)]
- The parameter *k* in the household utility function in equation (4) in Box V.6 is set to 0, which, together with the other parameter choices, has the consequence that the value of a statistical life is 159 times the GDP per capita[b)]

Over the course of the outbreak, households that are susceptible to the virus will respond by reducing consumption and labour supply as the number of infected people increases, cf. Figure A. These behavioural responses will, in themselves, reduce the spread of infection and thus the basic reproduction number in the period where the number of infected people increases, cf. Figure B. When the number of infected people subsequently begins to decline, households gradually increase their consumption and labour supply again, whereby the basic reproduction number gradually returns to 2.1.

The reduction of the spread of infection over the period during which the number of infected people increases has the consequence that the number of infected people peaks at a slightly lower level after 18 weeks (at approximately 16 percent of the population) than in the baseline SIR model in section V.2, cf. Figure C. The limitation in the spread of infection at the beginning of the outbreak also has the consequence that, as a result of a slightly lower degree of overshooting, slightly fewer people die than predicted by the baseline scenario in the SIR model in section V.2, cf. Figure D.

a) The three parameters, π_1, π_2 og π_3, in equation (1) in Box V.6 are thus scaled up proportionally relative to the assumptions in Eichenbaum et al. (2020a), where the basic reproduction number is 1.5 at the beginning of the outbreak.

b) For comparison, the Ministry of Finance in Denmark assumes that the value of a statistical life is 85 times GDP per capita.

BOX V.7 THE BASELINE SCENARIO, CONTINUED

Note that the figures below illustrate the course of the outbreak assuming that, at any given time, neither a vaccine nor an effective medical treatment has been discovered.

FIGURE A CONSUMPTION AND LABOUR SUPPLY

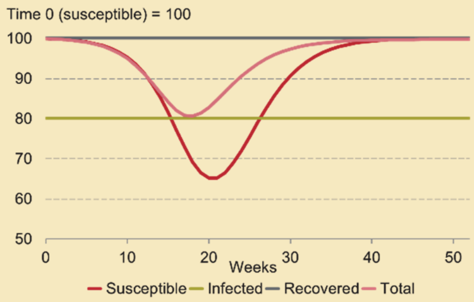


FIGURE B REPRODUCTION NUMBER

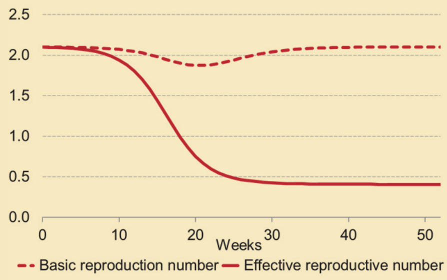


FIGURE C INFECTED

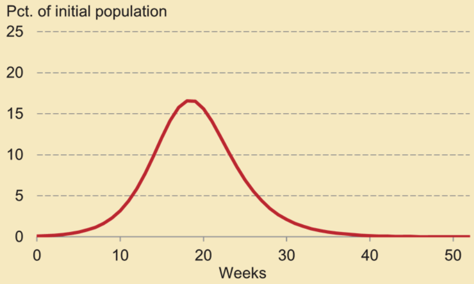
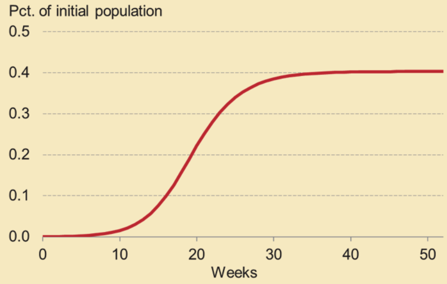


FIGURE D DECEASED



Notes In the model used, there is a one-to-one relationship between consumption and labour supply. Therefore, the relative changes in consumption and the relative changes in labour supply are identical. Figure A, therefore, illustrates the effect on both (with the initial level normalised to 100). The curve "Total" indicates total consumption / total working hours. The development in this reflects, among other things, compositional effects, i.e., that over time there are differences in the proportion of the population that is in the individual groups (susceptible, infected and recovered).

Source: Own calculations based on Eichenbaum et al. (2020a).

Illustration of optimal policy …

In the model, the authorities have the possibility of influencing general economic activity and, thereby, the spread of infection by applying a time-varying tax on consumption, which in fact also acts as a corresponding tax on earned income. This can be seen as a simple way of taking into account that the authorities can reduce economic activity by imposing restrictions on the business community or imposing actual lockdowns. In the following, the optimal policy, understood as the policy response that results in the sum of the individual citizens' welfare levels being as high as possible, is illustrated, given the assumptions in the model, including household preferences. In designing the optimal policy response, the authorities are faced with a fundamental trade-off between the need to avoid loss of human life and the need to avoid an excessive fall in production and consumption during the viral outbreak.

… in the baseline scenario and under four alternative scenarios

First, the results of the optimal policy in the baseline scenario are considered (i.e., using the assumptions that form the baseline scenario presented in box V.7). Next, the optimal policy is considered under four alternative scenarios:

1. Higher mortality rate of the virus
2. Higher value of a statistical life
3. Lower probability of a vaccine being discovered
4. Mortality rate of the virus depends on the number of infected (via capacity pressures in the healthcare system).

Optimal policy in the baseline scenario

A significant decrease in activity at the beginning of the outbreak is optimal

With the assumptions used in the baseline scenario, it is optimal to have a relatively aggressive policy response that, from the very beginning of the outbreak of the virus, limits the spread of infection by reducing total economic activity by 18 percent relative to the scenario without the optimal policy response, cf. Figure V.6. This is because there is some probability that a vaccine against the virus will be discovered. By reducing economic activity as soon as possible, and thus limiting the spread of infection, loss of human life can be avoided if a vaccine should become available within a short period of time.

Scenarios conditional on a vaccine and treatment not yet being discovered

Note that Figure V.6 illustrates the consequences of the optimal policy provided that no vaccine has been discovered at a given point in time, but under the assumption that one is expected to be available in one year’s time. The moment a vaccine is actually discovered, it is assumed, as previously mentioned, that the number of newly infected people will be zero in the future. Thus, the restrictions on economic activity can be lifted without loss of human life. Likewise, the restrictions on economic activity can be lifted without loss of human life if, at a given time, an effective medical treatment is discovered.

The number infected peaks at a lower level

With the optimal policy response, the reduced infection intensity due to the restriction of economic activity will cause the number infected to peak a little later than would be the case without the optimal policy. The level at which the number of infected people peaks is also lower than in the case without any policy response, cf. Figure V.6. Furthermore, it is optimal to allow the restrictions on economic activity to be phased out as the number of infected people begins to decline. Thus, it is ensured that the spread of infection is limited for a longer period of time and that the restrictions are phased out gradually as the number infected declines.

Undulation as a result of asynchronous paths

Note that, in the upper graph to the left in figure V.6, up to week 23 there is an undulation in the dashed curve, which shows the percentage gap between consumption (and labour supply) in the optimal policy case and consumption in the case without a policy response.[17] Thus, the gap decreases for a period, before it increases, and then continuously decreases from week 23. The temporary reduction in the gap is an indication that the people who are susceptible to the virus in the case without a policy response reduce their consumption to a relatively large extent as the number of infected people increases, as illustrated in box V.7. In the optimal policy case, a large part of this decline in consumption is brought forward to the beginning of the outbreak and, therefore, a smaller decline occurs subsequently. The subsequent expansion between week 18 and week 23 reflects that household consumption levels are normalised earlier in the case without the optimal policy response because the number of infected people peaks earlier.

Optimal policy involves some spread of infection

The optimal policy response means that there will be an ongoing spread of infection in the community. This is primarily justified in order to avoid an excessive decline in economic activity, but at the same time, it contributes to building up immunity in the population. Overall, this leads to the virus dying out a little later than in the case without the optimal policy response and in which a vaccine is never discovered. If a vaccine never becomes available, the total number of deaths will be reduced by 4 percent compared to the case without the optimal policy response. The fact that the number of deaths is reduced in this case reflects that the limitation of the spread of infection over a longer period of time reduces the total number of deaths.[18] If a vaccine is discovered before the virus dies out, the reduction in the number of deaths will be greater relative to the case without an policy response, cf. Figure V.6.

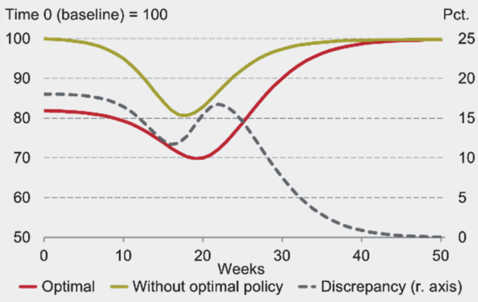
17) This is repeated in several of the scenarios considered below.

18) The optimal policy can thus be said to be a hedging strategy: On the one hand, there is an expectation that a vaccine will be discovered; on the other hand, immunity is also built up in the population in the event that a vaccine is never discovered.

FIGURE V.6 **OPTIMAL POLICY IN THE BASELINE SCENARIO**

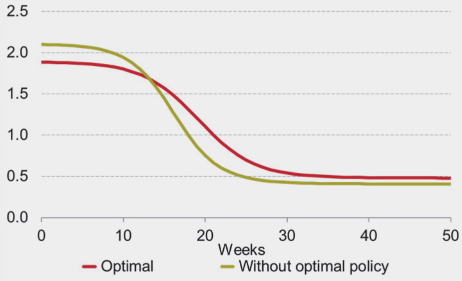
CONSUMPTION

The optimal policy implies a significant reduction in consumption and labour supply from the beginning of the virus outbreak relative to the case without the optimal policy …



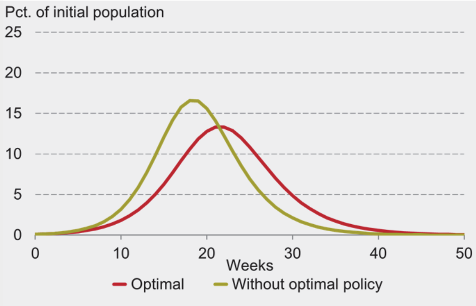
REPRODUCTION NUMBER

… and, hence, a reduction in the reproduction number.



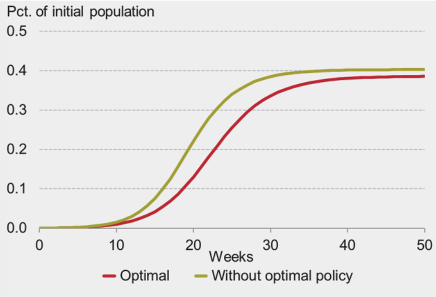
INFECTED

The optimal policy implies that the number of infected people peaks later and at a lower level than in the case without the optimal policy.



DECEASED

If a vaccine is not discovered, the number of deaths is reduced by 4 percent relative to the case without the optimal policy. This reduction can be significantly greater if a vaccine is discovered.



Notes: In the figure at the top left, “Gap (right axis)” indicates the percentage that total consumption (and labour supply) is lower in the optimal case compared with the case without a policy response. Note that the case without the optimal policy corresponds to the baseline scenario presented in box V.7.

Source: Own calculations based on Eichenbaum et al. (2020a).

Higher mortality rate of the virus

With higher mortality rates, greater restriction of activity is optimal …

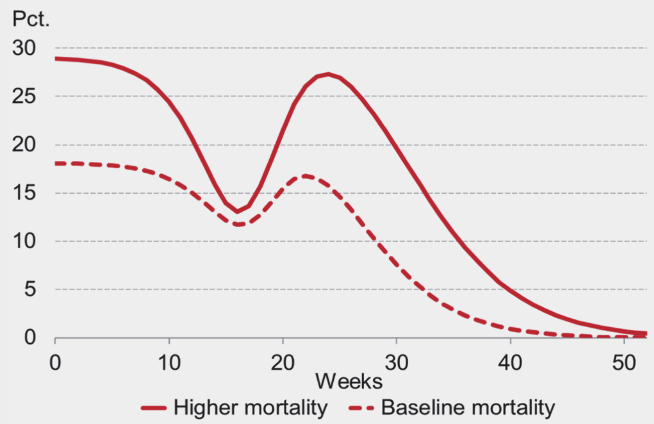
Figure V.7 presents the consequences for the optimal policy if the risk of death is 1 percent instead of 0.5 percent as in the baseline scenario. In the case without policy measures, this would increase the total number of deaths over the duration of the outbreak of the virus to 0.78 percent of the population and cause a greater decrease in consumption at the beginning of the outbreak than illustrated in box V.7. The optimal policy response in this case consists of an even stricter restriction of economic activity than in the baseline scenario, cf. Figure V.7. This is because the cost of people contracting the virus is now greater.

… and the activity restrictions are in place for longer

The optimal policy also means that the restrictions on economic activity are in place for longer than in the baseline scenario. This reflects that the benefit of waiting for a vaccine is greater when mortality is higher.

FIGURE V.7 REDUCTION IN CONSUMPTION

In the event of a doubling of mortality, the optimal policy implies a bigger reduction in consumption and labour supply during the outbreak of the virus.



Notes: See notes to figure V.6. Note that the dashed curve is identical to the dashed curve in the upper left graph in figure V.6.

Source: Own calculations based on Eichenbaum et al. (2020a).

Higher value of a life

Figure V.8 presents the consequences of the value of a statistical life (VSL) being increased by 60 percent compared with the baseline scenario.[19]

VALUE OF A STATISTICAL LIFE (VSL)

The value of a statistical life indicates society's willingness to pay for a small reduction in the risk of death. It can be interpreted as the total present value of each future life year one could expect to live.

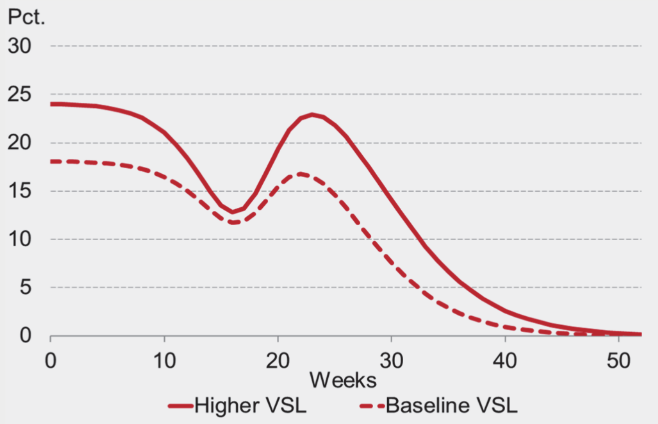
Higher VSL implies greater restriction of activity

A higher value of a statistical life, like a higher mortality rate, implies that it is optimal to impose heavier restrictions on economic activity during the outbreak of the virus compared with the baseline scenario, cf. Figure V.8. This reflects that the cost of infection to both the individual and society increases when the value of a statistical life is higher. There is thus a greater benefit in limiting activity and the spread of infection. However, in the case where a vaccine is not discovered, the reduction in the number of deaths will be only slightly greater than in the baseline scenario with a lower value of a statistical life.

19) This has been done by increasing the constant, *k*, in the utility function of households, cf. equation (4) in Box V.6.

FIGURE V.8 REDUCTION IN CONSUMPTION

With an increase in the value of a statistical life of 60 percent, the optimal policy implies a bigger reduction in consumption and labour supply during the outbreak of the virus.



Note: See notes to figure V.6. Note that the dashed curve is identical to the dashed curve in the upper left graph in figure V.6.

Source: Own calculations based on Eichenbaum et al. (2020a).

Lower likelihood of a vaccine being discovered

When a vaccine is less likely …

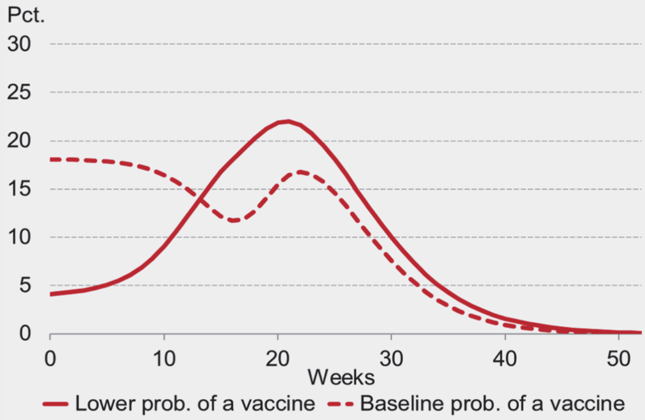
Figure V.9 presents the consequences for the optimal policy when the probability of a vaccine being discovered is 90 percent lower than in the baseline scenario above, corresponding to an expectation of it taking 10 years for a vaccine to be discovered. This significantly changes the time profile of the optimal policy response. The reason is that there is a lower expected gain from postponing the spread of infection in anticipation of a vaccine becoming available. Instead, herd immunity is more likely to be achieved by enough people contracting the virus, therefore, the purpose of the optimal policy is rather to reduce the extent of overshooting. Instead of a significant restriction of economic activity at the beginning of the outbreak, it is optimal to have fewer restrictions on economic activity in this case.

… the optimal policy response follows the number of infected to a greater extent

On the other hand, economic activity and the spread of infection are further limited as the number of infected people increases and the infection externality thus becomes more costly. Once the number of infected has reached its peak, the restrictions on economic activity are phased out. Due to the gradual phasing in and subsequent phasing out of the restrictions on economic activity, the number of deaths is reduced compared to the case without the optimal policy due to a lower degree of overshooting.[20]

FIGURE V.9 REDUCTION IN CONSUMPTION

With a low probability of a vaccine being discovered, the restrictions on economic activity will more closely follow the evolution in the number of infected people.



Notes.: See notes to figure V.6. Note that the dashed curve is identical to the dashed curve in the upper left graph in figure V.6.

Source: Own calculations based on Eichenbaum et al. (2020a).

20) Conversely, Eichenbaum et al. (2020a) show that the optimal policy response does not depend significantly on the likelihood of an effective medical treatment being discovered. This is because there is not a high cost as a result of people becoming infected if a treatment arrives in a shorter period of time. Unlike this, the group of currently infected people will not benefit from the vaccine. That explains why there is such a big difference in the significance for the optimal policy.

Mortality rate depends on the number of infected

If the mortality rate depends on capacity pressure in the healthcare system …

Figure V.10 presents the consequences for the optimal policy of a situation in which the mortality rate increases with the number of infected people. This reflects the consequences of increased capacity pressure in the healthcare system that reduces the quality of the treatment available to inpatients. Specifically, in the absence of policy measures, it is assumed that the mortality rate of the virus increases from 0.5 percent to 1.5 percent as the number of infected people increases. As a result, the number of deaths in total reaches 0.8 percent of the population over the duration of the outbreak of the virus.[21]

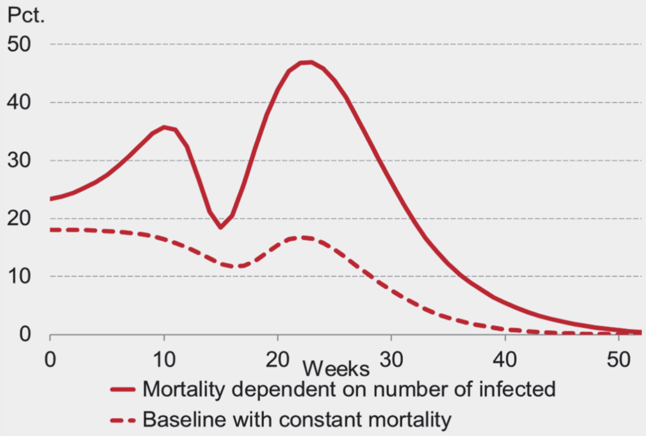
… there are additional externalities

The optimal policy implies a significant reduction in economic activity at the beginning of the outbreak and further restrictions in line with increases in the number of infected people, cf. Figure V.10. This reflects that there is an additional externality associated with the individual's consumption and labour supply decisions. Thus, individuals do not take into account the costs in the form of increased capacity pressure in the healthcare system if they become infected or infects others. Overall, the optimal policy means that the mortality rate only increases to 0.9 percent, and that the number of deaths is reduced by approximately one third relative to the case without policy measures and in which a vaccine is not discovered.

21) As in Eichenbaum et al. (2020a), it is assumed here that there is a quadratic relationship between the mortality rate and the number of infected people. Thus, when the number of infected is low, a further increase in the number of infected people will only lead to a small increase in mortality, while this effect is more pronounced the more infected people there are.

FIGURE V.10 REDUCTION IN CONSUMPTION

When the mortality rate increases with the number infected, it is optimal that economic activity be restricted to an increasing extent in line with the increasing number of infected people.



Notes.: See notes to figure V.6. Note that the dashed curve is identical to the dashed curve in the upper left graph in figure V.6.

Source: Own calculations based on Eichenbaum et al. (2020a).

Summary

Based on the economic-epidemiological model in Eichenbaum et al. (2020a), it is demonstrated that the optimal policy response to a virus outbreak can consist of significant restrictions on the economic activity from the start of the outbreak. This is the case if a vaccine is likely to be discovered within a shorter period of time, and in this case, there is a significant benefit in delaying the spread of infection. The extent to which economic activity should be restricted depends, among other things, on how high the mortality rate of the virus is and how much citizens are will to pay to reduce the risk of premature death. If a vaccine is unlikely to be discovered, the restrictions on economic activity should be intensified as the number infected increases, thereby reducing the extent of overshooting. This is also the case if the mortality rate of the virus depends on the capacity pressure in the healthcare system.

OTHER FACTORS OF RELEVANCE TO THE BASIC POLICY TRADE-OFFS

In the following, the results of other recent studies on the interaction between economic activity and epidemiology where the focus is on factors that affect the basic trade-off between avoiding loss of human life and avoiding excessive reductions in economic activity are discussed.

Benefits of testing

Several studies have pointed out that there can be significant benefits from using testing and quarantine measures to reduce the spread of infection rather than a general lockdown of the economy.

Random tests can enable targeted quarantine

Berger et al. (2020) take into account, for example, that those infected may be asymptomatic for a period but can still infect others. Against this background, they analyse the effects of random testing of asymptomatic people combined with quarantine in the event of a positive test (conditional quarantine) as people in quarantine have a lower risk of infecting others. They find that, compared to a general lockdown of the economy, random testing and conditional quarantine can reduce the negative economic impact without increasing the number of deaths. This is due to the fact that the quarantine measures can be better targeted at the infected, allowing economic activity to continue to a greater extent without creating too great a spread of infection. Berger et al. (2020) further find that testing and conditional quarantine postpone the time that the number of infected peaks. Thus, time can be gained, which, for example, makes it possible to build capacity in the healthcare system.

Testing in combination with quarantine can reduce deaths

Eichenbaum et al. (2020b) also discuss the use of random (mass) testing and conditional quarantine in an extension of their earlier model on which the results in this section are based. In the modified version, it is assumed that the infected are asymptomatic, and individuals therefore do not know their own health status.[22] The study distinguishes between two types of quarantine: smart containment and strict containment. Under smart containment, those who test positive are isolated in such a way that they do not transmit the infection through work or their consumer activity (equivalent to home isolation, where the authorities make consumer goods available). Under strict containment, the infected individuals are completely isolated so that they do not spread

22) The study finds that testing in the absence of quarantine measures will increase the spread of infection because people who find out they are infected are not at risk of becoming infected by consuming and working. Thus, in this model, they will exercise less caution than if they had been in doubt as to whether they were infected. This is a result of the fact that, as mentioned earlier, it is assumed that people’s behaviour takes no consideration for other people's well-being.

the infection via physical contact that is not related to consumption and work (equivalent to a more extreme form of isolation).[23] Eichenbaum et al. (2020b) find that smart containment that involves testing 38 percent of the population every week by the end of the first year roughly halves the number of deaths, just as the decline in the level of activity is reduced.[24] The latter effect is due to the fact that it becomes less risky to work and consume when infected people are more isolated. Strict containment means an even greater reduction in the spread of infection and the number of deaths. However, it also requires that a larger proportion of the population be tested (59 percent each week by the end of the first year) and this also means that the spread of infection is limited to such an extent that herd immunity is never achieved.

Temporary immunity may increase the benefits of testing and conditional quarantine

Eichenbaum et al. (2020b) also carry out a sensitivity analysis that takes into account that people who have been infected might only gain temporary immunity to the virus. In this case, the epidemic will flare up again from time to time as people become infected again. This will also lead to repeated periods of declines in economic activity. In this case, both smart containment and strict containment (to the extent mentioned above) would not only reduce the number infected and the number of deaths in the short term, but would also completely avert future outbreaks.[25] The presence of temporary immunity thus increases the potential benefit of conducting tests and implementing conditional quarantine.

Even with the cost of testing, intensive testing strategy can be optimal

Piguillem and Shi (2020) analyse random testing and conditional quarantine in a model where a proportion of those infected never show symptoms. Thus, there is a proportion of those individuals who have acquired immunity to the virus who are not aware of this. Piguillem and Shi (2020) point out that testing can both free up labour supply compared to a general lockdown and can help reduce the spread of infection. Unlike the two studies mentioned above, Piguillem and Shi (2020) take the cost of testing into account. They assume that the cost of testing one additional person is increasing in the extent of the testing. Even with these assumptions, they find that intensive testing is optimal. They further find that testing (combined with conditional quarantine) is a sub-

23) The study does not take into account that there may be costs associated with testing just as there may be costs associated with more quarantine facilities, for example, in the form of governments making hotel rooms available to quarantined people.

24) With the test strategy assumed in Eichenbaum et al. (2020b), more people gradually join the test group. When a person joins the test group, they remain there until they test positive (are infected) and subsequently test negative (have recovered).

25) Note that this result applies to a closed economy.

stitute for a more general lockdown. The number of deaths in the optimal testing scenario in the study is thus approximately the same as with a general lockdown, but the negative economic consequences as a result of lower production are significantly mitigated.

Contact tracing can be an effective tool

Another type of testing involves so-called contact tracing, where instead of being random, testing is targeted at people who have been in contact with infected people and, therefore, have a particularly high risk of being infected. If contact tracing is sufficiently well-functioning in the sense that a large proportion of those infected can be traced at low cost, it can be an economically effective tool compared to a widespread lockdown or no policy measures at all, cf. Alvarez et al. (2020). Even in cases where contact tracing is less well-functioning, it may be appropriate to use it as a supplement to shutdowns. The effectiveness depends on the extent to which it is possible to target the testing to catch all the suspected infected people, i.e., whether all the contacts can be traced and how costly this will be.

Gains from targeted restrictions

Several studies find that there can be significant gains from targeting restrictions towards vulnerable groups rather than imposing a general shutdown of the economy.

Targeted restrictions are more cost-effective than general shutdowns

Acemoglu et al. (2020), for example, carry out an analysis that includes three different age groups: young, middle-aged and older. They take into account that the risk of becoming infected, the risk of being admitted to hospital (conditional on having been infected), and the risk of dying from the virus depend on age. Acemoglu et al. (2020) find that targeted restrictions that cause the elderly to be less exposed to infection are significantly more cost-effective than general lockdowns. The number infected and the number of deaths is thus reduced, and at the same time the targeted restrictions enable the younger and middle-aged people to participate more fully in the labour market more quickly. This mitigates the negative economic consequences.

Appropriate to lift restrictions for younger people first

Rampini (2020) considers a model with two age groups: a younger age group that has higher labour market participation rates and suffers fewer complications in the event of an infection, and an older age group that is less likely to work and more likely to be hospitalised and to die from an infection. In the study, there is initially a general lockdown in place that has led to restrictions on all groups. By removing the restrictions for the younger age group first, the number of deaths, the pressure on the healthcare system and the financial costs of the measures can be reduced compared to a situation where the restrictions are removed later for all groups at once.

Substitution between consumer goods can reduce the cost of virus outbreaks

Krueger et al. (2020) point out that both the negative economic and the health costs of a viral outbreak can be significantly reduced when the fact that consumers can substitute between different consumer goods is taken into account. The study extends the model in Eichenbaum et al. (2020a) to include more sectors and consumer goods, and takes into account that different consumer goods are associated with different contagion risks. In the event of a virus outbreak, consumers will substitute away from the goods where consumption is associated with a relatively high risk of infection and towards goods where consumption is associated with a relatively low risk of infection. This in itself reduces the spread of infection and the number of deaths, and at the same time reduces the overall decline in economic activity. The study assumes that there are no frictions that prevent employees in sectors affected by the changed consumption patterns from moving to other sectors.

V.4 STRATEGIES IN CASE OF VIRUS OUTBREAK

This section picks up on the two preceding sections and discusses which strategy - containment, suppression or mitigation - is most appropriate from a purely socio-economic perspective. The answer depends on a number of economic and epidemiological factors as well as on policy trade-offs. With regards to the current COVID-19 pandemic, many of these factors are still unknown. Given the choice of strategy, various instruments may be suitable. Section V.5 discusses a number of these instruments.

Three types of strategy

There are three basic strategies for dealing with the outbreak of a virus: In the containment strategy, the purpose is more or less to eliminate the virus from the start and prevent it from spreading to the rest of the community. The mitigation strategy allows a controlled spread of the virus. The suppression strategy can be seen as a hybrid between containment and mitigation. Here it is accepted that the virus is in the community, but an attempt is made to limit and keep control of the spread of the infection.Such a strategy may be applicable in cases when, for example, it is not possible or if it is very costly to contain the virus.

OVERALL STRATEGIES

If action is taken early enough in a virus outbreak, it may be possible to apply a **containment strategy** and try to avoid an epidemic. This usually means that people who contract the virus are identified and isolated, for example with the help of contact tracing, before they have time to pass on the virus. A successful containment strategy may also require significant entry restrictions in order to avoid the emergence of new cases of infection from abroad. Taiwan is an example of a country that has largely followed a strategy in which attempts have been made to contain COVID-19, cf. Box V.8.

A **suppression strategy** tries to prevent the virus from spreading widely in society and, thus, to keep transmission of the virus low, for example, until a vaccination is available. Denmark and Norway have used a suppression strategy in connection with the outbreak of COVID-19, cf. Box V.8.

A **mitigation strategy** allows the virus to remain in the community for an extended period of time with the aim of achieving herd immunity. Instead of eliminating the virus, this strategy seeks to ensure a controlled spread of infection and to mitigate the consequences of the outbreak, including the pressure on the healthcare system's resources. This potentially avoids the cost of more rigorous infection control strategies necessary to suppress or contain the virus. Sweden is an example of a country that has more or less followed a mitigation strategy, cf. Box V.8.

The Danish authorities have used a "hammer and dance" strategy

An example of a suppression strategy is the "hammer and the dance" strategy, cf. Pueyo (2020). Denmark has used this strategy since the spring.[26] The strategy is to first hit transmission of the virus hard with aggressive lockdown measures (the hammer) and then gradually reopen the economy while the infection is kept in check by more targeted measures, such as contact tracing (the dance). The strategy may, for example, be appropriate if the spread of infection is to be suppressed from a starting point where the virus is relatively widespread in the population.

[26] The term has subsequently been used by Prime Minister Mette Frederiksen to describe the Danish strategy, cf. Tv2 (2020) (https://www.tv2lorry.dk/tv2dk/mette-frederiksen-vi-vil-se-flere-lokale-nedlukninger-resten-af-aaret).

BOX V.8 COVID-19 MANAGEMENT STRATEGIES

Taiwan is an example of a country that has used a containment strategy in connection with the outbreak of COVID-19. For this purpose, a combination of control and quarantine of people entering the country, testing and surveillance has been used, cf. Cheng et al. (2020). Taiwan has more or less prevented the spread of the virus within its borders. Most of the infections have been in travellers arriving from abroad; thus, the spread of infection from these people has been checked.

Among the Nordic countries, Norway and Sweden have followed different strategies in relation to the outbreak of COVID-19 in 2020.

Sweden has largely avoided major lockdowns and actual bans. Instead, the focus has been on encouraging the population to exercise caution by, among other things, maintaining a physical distance from others. In particular, authorities have urged senior people to avoid contact with others. In some areas, actual restrictions have been introduced, for example, on visits to nursing homes, as well as bans on gatherings, and online learning was introduced in parts of the education system.[a)]

Norway, on the other hand, has pursued a strategy that has the character of suppression. Already in mid-March, a major lockdown was introduced that included online learning in schools, closure of restaurants and fitness centres and restrictions on entry into the country.[b)] In addition, Norway has utilised testing to a significant extent.

At the beginning of the virus outbreak, Denmark followed a containment strategy in order to try to avoid the virus being introduced into the community. Relatively quickly, the Danish authorities then switched to another type of strategy that was more mitigation in character, as the purpose was to flatten the curve so that the capacity pressure on the healthcare system did not become too great at any point.

In March, however, a comprehensive lockdown of society was imposed in order to reduce the reproduction number. These lockdown measures included, among other things, schools going to online learning, lockdowns of a number of economic activities, work-from-home by parts of the public sector employees, closure of Danish borders, etc. This can be seen as the first part of the transition to the hammer and dance strategy, which has the character of a suppression strategy. Since then, the authorities have increasingly moved to the other part of the strategy with the gradual reopening of the economy combined with a massive test and contact tracing effort, continued restrictions on travel and certain types of business activities, requirements for masks to be worn on public transport and various measures targeted at local outbreaks.

a) See, for example, https://www.folkhalsomyndigheten.se/the-public-health-agency-of-sweden/communicable-disease-control/covid-19--the-swedish-strategy/

b) See for example, https://www.businessinsider.com/how-sweden-and-norway-handled-COVID-19-differently-2020-4?r=US&IR=T

There are different variants of containment, suppression and mitigation strategies

Containment, suppression and mitigation are major categories of strategies, and within each category there are several different variants, which are characterised by the number of infected people that is acceptable at different points in time over the course of the outbreak. An example of an extreme form of mitigation is a strategy where viruses are allowed to spread freely without any intervention from the authorities. Such a strategy will lead to a relatively large number of people becoming infected as a result of, among other things, overshooting, cf. section V.2. However, this may be appropriate in epidemics of relatively harmless diseases. The transition between mitigation and suppression is also fluid in the sense that one can imagine strategies where the infection is kept simmering through a longer outbreak, so that the proportion who have been infected gradually increases. Such a strategy can either be characterised as a loose suppression strategy or a very slow mitigation strategy.

A strategy can be achieved by using several different instruments

A strategy can, in principle, be achieved by employing a combination of several different instruments that reduce the spread in the community, although there may be differences in which instruments are best suited for different strategies. Section V.5 describes some of the instruments that can be used to combat COVID-19 and epidemics in general, and discusses the circumstances in which they are applicable to the various strategies.

CHOICE OF STRATEGY

Choice of strategy depends on several uncertain economic and epidemiological conditions

Based on section V.3, it is possible to identify some of the factors that determine which strategy is most appropriate, cf. Table V.1. This is not meant to be an exhaustive list, but an overview of the factors that are important. As for the COVID-19 pandemic, there is significant uncertainty about several of the factors. Overall, therefore, it is not possible at this stage to determine which strategy is most appropriate.

High cost of infection favours suppression or containment …

The greater the cost of the disease, the more appropriate it is to follow a suppression strategy or, if possible, a containment strategy, thereby minimising the number of infected people. The costs are greater, for example, the higher the mortality rate, and the more people who suffer long-term health effects. A high value of human life will also favour this approach. In addition, capacity in the healthcare system plays a role in the cost; the more limited the capacity, the higher the excess mortality when there are many infected people. When the cost of infection is greater, it becomes more advantageous to seek to curb the spread of the virus.

… as does uncertainty about the consequences

In many cases, the mortality rate and extent of long-term health effects of the disease are not known, and this may in itself be an argument for curbing or suppressing the spread of the infection. Thus, greater uncertainty about costs will typically favour strategies that reduce the number of infected people in order to reduce the risks.

Early detection may make containment possible

If the disease is detected at an early stage when the infection is not yet widespread in the community, then the need for major lockdown measures to curb the spread of the infection is reduced. If this is possible, the cost of containment of the spread of the infection is reduced, which makes it more advantageous to use a containment strategy. In relation to COVID-19, however, the containment strategy is complicated by, among other things, the fact that some of those who are infected with COVID-19 do not show symptoms, and some people who later develop symptoms are contagious before they show symptoms.

High likelihood of a vaccine and good transmission control favour suppression or containment

In addition, technology plays a role in the choice of strategy. If a vaccine is expected to become available in the near future, it will become more attractive to suppress or even contain a virus. The cost of limiting the spread of infection is also determined by the technological and institutional possibilities for various forms of transmission control. If contact tracing is effective and not very costly, it is easier and cheaper to suppress or contain a virus. The same applies if it is possible to limit the arrival of the infection from abroad in a cost-effective way.

High cost of lockdowns favour mitigation

Suppression typically involves a certain element of lockdown or at least the risk of it, as it is uncertain, especially with new and unknown diseases, whether the epidemic can be suppressed completely without the use of lockdowns. The greater the cost of lockdowns, the more favourable it is to opt for a mitigation strategy rather than spending a lot of resources on suppression or containment. The costs of lockdowns are greater if there are negative long-term economic effects of bans on activity. For example, important knowledge about work processes and organisational knowledge can be lost if enterprises close due to restrictions on their business activity, and this can damage production in the long run. However, these effects may be mitigated by support schemes put in place to limit business closures.

Ample means of isolating the vulnerable and lasting immunity favour mitigation

The easier it is to isolate vulnerable people, the lower is the cost of accepting a more general spread of infection in the community. Having sufficient means to protect vulnerable people, therefore, also speaks in favour of choosing the mitigation strategy. Lasting immunity will also favour mitigation: If those who recover have gained immunity, it is possible to achieve herd immunity in the population. This reduces the cost of the infection spreading relative to the situation where it is possible to become infected repeatedly.

With a new and unknown virus, altered behaviour can mitigate the consequences but prolong the outbreak

Particularly with a new virus where there is considerable uncertainty about the health consequences, it may be the case that people themselves choose to exercise a high degree of caution in their behaviour and, for example, isolate themselves from other people to a greater extent. As mentioned in section V.3, these behavioural responses can mitigate the health costs of a virus outbreak. Seen in isolation, this means that the need for policy measures to limit the spread of infection is reduced, which can therefore make the mitigation strategy more attractive. However, the behavioural responses may also mean that it could take too long for herd immunity to be achieved relative to what is desirable. Seen in isolation, this makes the mitigation strategy less attractive.

Easy substitutability in consumption can pull in both directions

Under certain conditions the epidemic will involve a limited number of infected people, even if left to spread freely, cf. Krueger et al. (2020). This may be the case, for example, if there are such good substitution possibilities in consumption that consumers themselves replace infection-risky consumption of goods and services with consumption of less infection-risky goods and services. This reduces the spread of infection even in the absence of policy measures and, hence, reduces the need for the authorities to step in to curb the spread of infection. What's more, better substitution possibilities can also reduce the cost of lockdowns, as consumption closed industries can be more easily shifted to consumption from industries that are still open.

TABLE V.1 IMPORTANT FACTORS FOR CHOOSING A STRATEGY

Factors that favour suppression or containment	Refer to
High mortality rate / long-term health effects of the disease	Section V.3
Uncertainty about mortality rate and long-term health effects	
High probability of a vaccine being discovered within a shorter period of time	Section V.3
Limited treatment capacity in the healthcare system	Section V.3
Sufficient capacity to test and trace	Alvarez et al. (2020)
Ability to limit infection from abroad	
High value of a statistical life	Alvarez (2020)
Early detection so lockdowns can be avoided	

Factors that favour mitigation	Refer to
Sufficient means to isolate vulnerable groups	Acemoglu et al. (2020)
Lasting immunity in the recovered	
Good substitution possibilities in consumption[a)]	Krueger et al. (2020)
Permanent productivity reductions due to locking down of economic activity	

a) At the same time, however, this will also reduce the cost of lockdowns in parts of the economy, which may be part of a suppression strategy.

V.5 INSTRUMENTS FOR COMBATTING THE SPREAD OF INFECTION

Which instruments are most suitable for achieving different strategies?

Different strategies imply different limits on how much and how fast the infection is allowed to spread in the community: In mitigation, the infection spreads at a controlled rate; in suppression, widespread infection must be prevented; and in containment, the spread of infection must be stopped completely. In all circumstances, however, measures are needed to reduce the infection, albeit to varying degrees. This section discusses which instruments are most appropriate for pursuing the various strategies.

Appropriate choice of instruments takes into account contagion effects and costs …

There are several factors that need to be considered in determining which instruments should be implemented to achieve a desired strategy. First, it is relevant to look at how effective an instrument is at reducing infection relative to what the instrument costs society. The costs to society can be, for example, expenses associated with detecting the infection or lost production due to the closure of business activities.

… as well as distribution and uncertainty

In addition, distributional and uncertainty effects may be taken into account. Distributional effects become relevant if measures such as the lockdowns of economic activity affect vulnerable groups differently from others. Uncertainty is particularly relevant in the case of COVID-19 and other newly emerging diseases, as the knowledge base is incomplete. For example, there is still only limited knowledge about the effect of the various measures on the spread of the infection, the health consequences of the disease in the short and long terms and the basic epidemiological parameters, such as incubation period and length of the infectious period.

The effectiveness of the instruments influences the choice of strategy

The effectiveness of the instruments available also affects which strategy is most appropriate. Thus, if there are many relatively inexpensive and effective instruments available, then this favours a containment or suppression strategy in which transmission is limited. Conversely, if it is not possible to limit the infection without expensive lockdowns, then this favours mitigation.

This section is empirical and primarily relevant to COVID-19

Much of this section is empirical and draws on the knowledge gained from the spread of COVID-19. Therefore, the discussion in this section is primarily relevant to COVID-19, although it will probably also be applicable if a similar epidemic should occur in the future.

Contents of the section

The section first discusses lockdowns of various business and non-business activities. Next, several testing strategies are discussed, such as contact tracing and mass testing. Finally, a number of other measures are presented that are not related to lockdowns or testing.

LOCKING DOWN OF ACTIVITIES

Banning activities involving physical proximity

One possible instrument to reduce transmission is to impose regulations to limit activities associated with physical proximity. This can include both business and leisure activities, for example, gatherings of groups of people in clubs, churches and the like, or gatherings in public areas. The idea is to bring about greater physical distance between people and thus reduce transmission of the virus.

Lockdowns have probably reduced the transmission, …

Studies from a number of countries show that lockdowns have meant sharp reductions in the spread of COVID-19. A study across 11 European countries in the spring of 2020 finds that the lockdowns examined reduced the spread of COVID-19 by 81 percent, on average, cf. Flaxman et al. (2020). Another study across US counties concludes that various lockdown measures significantly reduced the growth in the number of confirmed infections, cf. Courtemanche et al. (2020). Studies from China and Italy draw similar conclusions, cf. Tian et al. (2020) and Gatto et al. (2020). These studies on the effect of lockdowns and other measures are discussed in more detail in Box V.9.

… but it's difficult to distinguish effects of lockdown from other factors affecting the spread of the virus

A challenge with the studies is that it can be difficult to distinguish the effects of the lockdowns from the effect of other changed factors. First, lockdowns will typically be implemented at the same time as other measures aimed at reducing the spread of the virus, making it difficult to determine what is the real driving force behind subsequent changes in the spread of infection. Second, even in the absence of interventions, the population can choose to increase physical distancing and otherwise change behaviour to avoid being infected. This may be partly driven by selfish motives (the fear of becoming infected) and partly by altruistic motives (consideration for others). These self-selected changes in behaviour often occur in response to a wider spread of the infection, cf. Engle et al. (2020). As lockdowns and other policy measures typically also take place during periods when the number of infections is increasing, it is difficult to determine the extent to which a subsequent decrease in infections is due to the measures implemented or to the self-selected behaviour.[27]

27) There may also be interactions between different measures, which make it difficult to distinguish the effects from each other. A lockdown can, for example, cause the directives issued by the authorities about maintaining a physical distance from other people

Immediate costs of general lockdowns are high

General lockdowns, such as the one introduced in Denmark during the spring of 2020, can have major immediate welfare costs. However, these costs must be weighed against how the evolution of the spread of the virus in the situation with no general lockdown would affect the economy. If, for example, the desired strategy is to curb the spread of infection, it is possible that a general lockdown today would mean that a more extensive general lockdown in the future could be avoided. It may also mean that increasing transmission, and the subsequent negative consequences for consumption and employment, are avoided, cf. section V.3. Thus, locking down today rather than at a later date may involve a lower cost over a longer period of time.

Prioritising lockdowns based on the contagion effect, cost, distribution and uncertainty

There are several factors that can be considered when prioritising which activities to lock down first. First, the effect on transmission which depends on the nature of the activities being restricted and the nature of the disease in question should be considered. For example, the transmission of COVID-19 can increase if an activity involves many people standing close to each other for a long time. Under such circumstances, the effect of a lockdown will be large. Second, it is appropriate to consider the costs to society of locking down the various activities. The cost will typically depend on both the direct welfare gain from performing the activity and on the indirect effects through the influence on other activities. Indirect effects occur, for example, because the production of certain inputs such as electricity and intermediate goods is important for production in other firms. Other factors that are relevant to prioritising activities to lockdown are the distributional and uncertainty implications.

Less knowledge about costs and benefits of locking down non-business activities

There is less knowledge about the costs and benefits of measures that lock down most non-business activities, such as gatherings, travel restrictions and lockdowns on households (i.e., stay at home orders). As mentioned above, empirical studies indicate that lockdowns have generally curbed the spread of COVID-19, but it is difficult to distinguish between the effects of locking down of different types of activities. In addition, it is difficult to calculate the welfare loss from locking down non-business activities, since leisure activities such as visits from friends and family are not traded in a market and, therefore, do not have a market price that can be used to value them.

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to be taken more seriously. Such an effect will not be attributable to either the directives or the lockdowns, but to a combination of both measures.

BOX V.9 **MEASUREMENTS DECREASING THE SPREAD OF THE CORONAVIRUS**

A number of studies look more closely at the effect of so-called non-pharmaceutical measures on the spread of COVID-19. Non-pharmaceutical interventions cover restrictions on various infection-spreading activities and other policy instruments that do not involve medical treatments. The main focus in the following is on empirical research into the effect of various measures that has been published in a peer-reviewed journal. The literature is new and rapidly growing, so the implications can change quickly.

Flaxman et al. (2020) examine the consequences of various policy measures for the spread of COVID-19 in 11 European countries, including Denmark. The method is a structural estimation of an epidemiological model where the reproduction number is allowed to vary depending on the policy pursued. The five types of policies examined are: School closures, mandates and calls for self-isolation, bans on public events, calls for physical distancing, and lockdowns. Lockdowns are defined as restrictions on social interactions, including bans on public assembly, closure of educational institutions (including schools), public and cultural institutions, and stay-at-home orders. Thus, lockdowns will typically include, or be an extension of, several of the other types of restrictions. In their study it is not possible to distinguish the effects of lockdowns from the effects of the other measures that, according to Flaxman et al. (2020), may be due to the timing of the interventions coinciding.

Courtemanche et al. (2020) examine the effects of various infection control measures on the number of confirmed COVID-19 cases in US counties. An event study approach is used to analyse the impacts of the introduction of the various initiatives at a time in the past on the evolution of the outbreak. This method makes it possible to examine whether there are identification problems in the form of different trends in the spread of infection before and after the intervention. Courtemanche et al. (2020) don't find any evidence against the identification strategy. Four different measures are examined: lockdowns (so-called shelter-in-place/stay-at-home orders), closures of public schools, bans on large social gatherings and closure of entertainment-related businesses, such as bars, restaurants and gyms. The authors find significant effects of lockdowns and of closing entertainment-related businesses, but not of school closures or bans on large public gatherings. Courtemanche et al. (2020) note that the absence of statistically significant effects for the latter two types of measures may be due to a high level of uncertainty, or that schooling and larger assemblies have been replaced by more informal social activities. Therefore, it is appropriate to consider whether this type of substitution is feasible when evaluating the effects of various measures. Tian et al. (2020) examine the effects of infection-reducing measures during the first 50 days of the COVID-19 epidemic in China. They use a so-called Markov chain Monte Carlo method to estimate an epidemiological model before and after the introduction of various policy measures. The method selects the model's parameters to fit the data on the number of infected people and movements of the population across 296 cities. The first conclusion is that the virus spread faster to areas that had received more travellers arriving from Wuhan, and that travel restrictions have slowed the spread. The second conclusion is that there are statistically significant effects of the suspension of public transport as well as the combination of bans on gatherings and closure of entertainment-related businesses.

BOX V.9 MEASUREMENTS DECREASING THE SPREAD OF THE CORONAVIRUS, CONTINUED

Gatto et al. (2020) examine the effects of infection reduction measures in Italy. As in Tian et al. (2020), a Markov Chain Monte Carlo estimation is used to estimate the parameters of an epidemiological model. Epidemiological data and data on population movements across 109 areas are used. The conclusion is that the measures significantly reduced the spread of the virus. The measures are divided into two groups according to when they were introduced. The effect is estimated as reductions in the model parameters that determine the spread of infection at the national level. Gatto et al. (2020) note that, therefore, the estimates reflect the overall effects of various changes that reduce the transmission of infection; thus, it is not possible to distinguish the effect of different policy measures from each other.

A number of indicators shed light on costs …

With regard to the lockdown of various business activities, it is possible to illustrate the costs and benefits on the basis of four indicators, which are calculated at the industry level, cf. Table V.2. The costs are illustrated firstly by the loss of production, calculated as reduction in the value added for the industry in question. The amount of lost production indicates the direct loss of output associated with the lockdown of the industry.[28] Another indicator that is not necessarily related to the size of the industry is whether the industry is essential to the functioning of society. This typically applies to production that supports basic needs, such as security, food and health. A third indicator is the ability to work from home, which, when it is possible, reduces production losses when access to the physical workplace is prevented due to lockdowns.

… and benefits of business closures

The benefits of locking down businesses are measured using an index of physical proximity to other people at work. This index highlights the potential for the transmission of infection associated with the business activity and thus the benefits in the form of a lower number of infections if the activity were locked down. This is supplemented by a measure of the proportion of unique visitors in selected industries in the United States. This measure is relevant, as the spread of infection can be greater in business activities where there are many visitors who would not otherwise interact in everyday life.

28) In addition, there may be indirect effects of lockdowns as a result of disruptions to deliveries in the supply chains. These can, for example, be read from the input-output tables in the national accounts, cf. Andersen et al. (2020b).

TABLE V.2 COSTS AND BENEFITS OF LOCKDOWNS

Indicators of cost	Indicators of benefits
Value added	Index of physical proximity
Categorisation of essential industries	Proportion of unique visitors in selected industries
Work-from-home index	

Note: The table shows the cost and benefit indicators included in this section.

Regulations other than bans

Instead of banning activities, it is possible to introduce legislation that, in various ways, aims to increase the physical distance between people. For example, there may be a limit on the number of customers per square metre, distance requirements in restaurants or restrictions on opening hours in nightclubs and bars. Such restrictions also have costs for society, but they are lower than if those activities were completely banned. On the other hand, the effect on the spread of the infection is also expected to be smaller.

Costs of locking down business activities

Loss of production from lockdowns is a cost to society

If a business activity is locked down, a production loss occurs and this is a cost to society. If production is stopped completely, the immediate loss depends on the value of the lost production.[29] If there are minor restrictions and it is still possible to keep parts of the business open, the loss will of course be less. This also applies in occupations where the physical workplaces are closed but the businesses can continue to operate by having their employees work from home, cf. the discussion below.

Reallocation of labour and capital will reduce production losses

Over time, labour and capital from locked down industries will seek employment in the open sectors of the economy, thereby increasing production in these industries and reducing total production losses. The speed and extent of this reallocation depends on several factors. Aid packages that retain labour and capital in the locked down indus-

29) The direct loss will be greater than the value of the output. This is because the value of the output is assessed at market price, which reflects the marginal gain from consuming the product. However, when the consumption volume is reduced, the price increases, which reflects the welfare gain from consumption. For example, a greater welfare loss will result from reducing the number of annual visits to restaurants from 1 to 0 than from 12 to 11. The excess loss depends on the price elasticity, which reflects, among other things, how easy it is to substitute other goods for restaurant visits.

tries will dampen the reallocation as long as they are in force. Economic conditions and other factors can affect the demand for labour and capital in the other sectors of the economy, and thus how quickly resources are redirected there. The reallocation is also affected by whether the released labour and capital are of a type that can be used in production in the businesses that remain open. Finally, business expectations can also play a role - if the lockdown is expected to be prolonged, the incentive to close the business and allow capital and labour to be used elsewhere will increase.

GVA as a measure of immediate production loss

Gross value added (GVA) measures the value of production in an industry and thus indicates the direct production loss of closure, cf. Figure V.11. This indicates the production loss for the industry in the case where all activities are stopped - if only some of the production activities are restricted, the effect will be smaller.

Indirect effects on other sectors of the economy

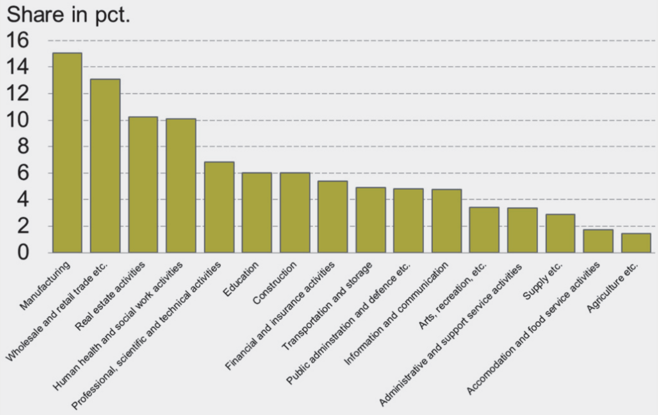
In addition to the direct effects of restrictions on business activity, there will be indirect effects on other industries. These effects can be due to lower demand or lack of supplies of goods and services. In addition, the closure of day care centres and primary schools (particularly the lower grades) may have indirect effects on production by reducing parents' effective labour supply.

Essential industries

The production of some industries is so important to the maintenance of society that it is difficult to do without it. This applies to the provision of goods that meet basic needs - these can be, for example, food, water, security and health. It can also be infrastructure that is necessary for maintaining communication and transport of people and goods. This is typically production that is important, even if the value added is not necessarily high.

FIGURE V.11 GROSS VALUE ADDED

Gross value added is a measure of the direct loss of production by closing down a sector.



Source: Statistics Denmark, National Accounts and own calculations.

US government list of essential industries, …

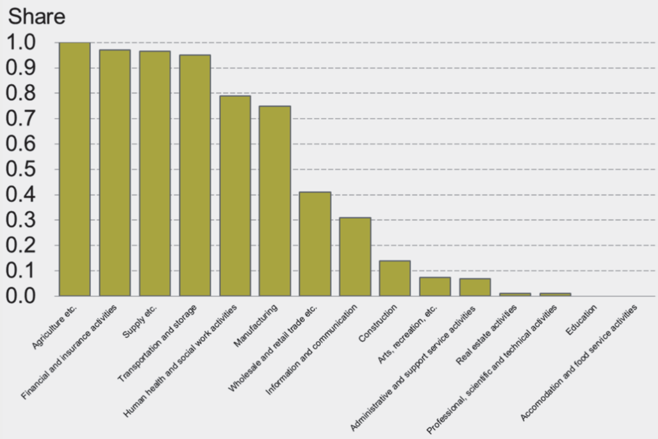
In order to shed light on which parts of the economy are essential for the maintenance of society, the following uses the US Department of Homeland Security's assessment of which industries are part of the country's so-called critical infrastructure, cf. Box V.10. The American list of industries is used, as Denmark does not have an official list, cf. Jensen (2018). The results must, therefore, be seen in the light of the fact that the categorisation of essential industries may be different in Denmark.

… which supports food production, infrastructure, transport, health and safety

Industries that are considered essential by the US authorities are typically characterised by the fact that they contribute to either food production, infrastructure, transport, health or safety, cf. Figure V.12. It includes both industries that directly contribute to keeping these functions going and industries that have a more indirect contribution. An example of the latter is the construction industry, which is responsible for the repair and construction of physical infrastructure, such as roads and railways. Another example is the parts of the retail sector that sell food and medicine.

FIGURE V.12 ESSENTIAL INDUSTRIES

The US government considers industries within e.g. food production, infrastructure and health as essential.



Notes: Proportion of Danish employees working in a sub-industry that by the US authorities is described as being essential for society. See Box V.10 for details on data and definition of industry group.

Source: Own calculations based on Mongey et al. (2020) and register data.

BOX V.10 INDUSTRYLEVEL DATA

Essential industries

The index of essential industries is from Mongey et al. (2020). They use the classification from Tomer and Kane (2020), which is based on the Department of Homeland Security's assessment of US essential industries. The index is a discrete variable equal to 1 if the industry is essential and 0 if it is not. The US industries are converted into Danish industry codes using the industry link from Eurostat, which links US NAICS codes to European NACE Rev. 2 codes. In some cases, the link between US and Danish industries is not one to one, but one-to-many or many-to-one. Here, the industries are linked using the same method that Dingel and Neimann (2020) use to link US job functions with Danish job functions, as employees in the US and employees in Denmark are used as weights. Danish employment is obtained from register data and the data for the US are from Mongey et al. (2020). It is not possible to link the industries within the "agriculture, etc." and “public administration, defence and police” industry groups. Therefore, the industry group "agriculture etc." is set. to 1, as the Department of Homeland Security (2020) states that food production is essential. "Public administration, defence and law and order" are omitted, as it is not immediately possible to determine which of the sub-sectors in the group are essential.

The final index for essential industries is calculated as an average of the number of employees in each industry group. An index of, for example, 0.6, will thus indicate that approximately 60 percent of the employees in the group work in a Danish industry where the corresponding US industry has been declared essential by the US authorities. The definition of industry groups is given at the end of this box.

Work from home

The first index for work from home is from Dingel and Neiman (2020) and is a discrete variable that assumes the value 1 if working from home is possible. Dingel and Neiman (2020) construct the index of job functions in the United States (job functions indicate types of jobs, such as cooking work and legal work). The construction of the index is based on the so-called O*NET database, which contains characteristics of each job function. Based on these characteristics, whether the possibility of working from home can be ruled out is determined. For example, a job function is coded as unsuitable for working from home if it involves daily outdoor work or if it depends, to a large extent, on the operation of vehicles or mechanised equipment.

BOX V.10 INDUSTRYLEVEL DATA, CONTINUED

The second work-from-home index is constructed by del Rio-Chanona et al. (2020). The index is compiled at the job function level and indicates the proportion of work activities that can be performed at home. This index is also based on O*NET data. In O*NET, each job function is linked to a certain number of work activities. Del Rio-Chanona et al. (2020) make a subjective assessment of whether each work activity can be performed at home. Next, the index for each job function is calculated as the proportion of work activities that can be performed from home. In contrast to the first index, the second index can thus assume more values between 0 and 1, which can give a more nuanced picture of the possibilities for working from home. On the other hand, the second index is primarily based on the authors' subjective assessments of the possibilities of performing various work activities from home. In contrast, the first index is defined on the basis of characteristics of jobs, which the authors have not defined themselves, but instead have taken from O*NET data.

The work-from-home indices have been calculated for US job functions and linked to Danish job functions using the method of Dingel and Neiman (2020), which is also used above to link Danish industries with essential industries in the US. For this, data for Danish employment from the register-based labour force statistics for 2018 are used.

Physical proximity indicator

The first indicator of the spread of infection shows physical proximity to others at work and is from Mongey et al. (2020). They construct the index for US job functions based on O*NET data on workers' responses to a survey question on how physically close they are to other people when performing their current job. The method from Dingel and Neiman (2020) is used to connect US job functions to Danish job functions. Then, register data is used to calculate the index for the average employee in each industry group.

Industry definitions

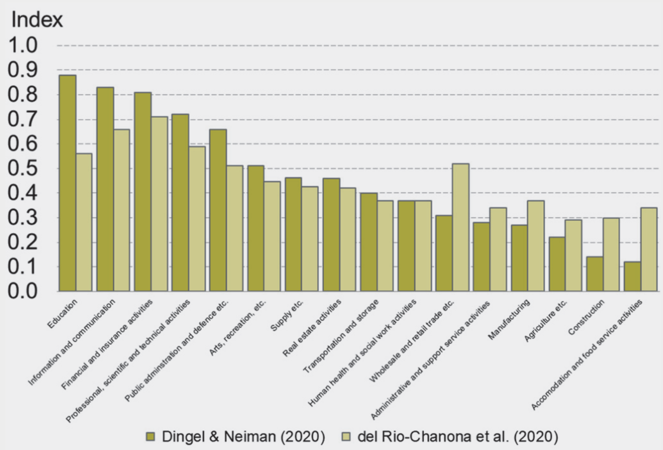
The industry grouping in this section is based on Statistics Denmark's 19-group industry codes, but for the sake of readability, the following Denmark's Statistics' industry groups: “B Mining and Quarrying”, “D Electricity, gas, steam etc.” and “E Water supply, sewerage etc.” are aggregated into one group called “Supply, etc.”, and the groups “R Arts, entertainment, recreation activities” and “S Other service activities” are aggregated into one group called “Culture, leisure, etc.” For the remaining groups, the 19-grouping standard classifications are used, however, with the following names: "Agriculture, etc." corresponds to Statistics Denmark's group A, “Industry” to C, “Building and construction” to F, “Trade” to G, “Transport” to H, “Hotels and restaurants” to I, “Information and communication” to J, “Financial and insurance” to K, “Real estate and rental” to L, “Knowledge services” to M, “Travel agencies, cleaning, etc.” to N, “Public Administration, defence, law and order” to O, “Education” to P and “Health and Social Services” to Group Q.

Working from home is possible in a variety of office jobs

Working from home is primarily possible in service occupations that involve a lot of office work, cf. Figure V.13. The two work-from-home indices are placed on a scale from 0 to 1, where 0 indicates that working from home is not possible at any of the workplaces in the industry group, and 1 indicates that working from home is possible at all workplaces. The indices are constructed on the basis of US job data and are based on two different methods and calculated for the average employee in Denmark in the different industry groups, cf. the description in Box V.10. Both indices indicate that 41 percent of all Danish jobs could be performed at home. According to the two indices, working from home can be done in most jobs in information and communication, financial and insurance, and knowledge services. This suggests that it is possible to limit physical activity in a large number of jobs without stopping production. In terms of teaching, the two indices differ significantly from each other, indicating uncertainty as to whether working from home is possible in this industry. For most other industries, the two indices more or less agree.

FIGURE V.13 WORKING FROM HOME

Opportunities for working from home vary across industries and are typically better in industries with a lot of office work.



Notes: The two indices indicate the homework opportunities for the average employee in different industry groups. See Box V.10 for details and definition of industry groups.

Source: Own calculations based on Dingel and Neiman (2020), del Rio-Chanona et al. (2020) and register data.

Productivity can be affected by working from home

An increased amount of work from home can affect productivity, and such an effect is not covered by the two indices. Bloom et al. (2015) find a positive effect of working from home on the productivity of Chinese employees in a call centre. A randomly selected group of employees worked at home for nine months, while a control group continued to work in the office. However, it is uncertain whether the effect would apply to Danish conditions during the COVID-19 pandemic because, e.g., in the study it was voluntary for the employees to participate in the experiment, and because they physically attended the workplace one day a week. Bartik et al. (2020) investigate the consequences for the productivity of working from home during the COVID-19 pandemic using two surveys of US businesses. The results point in different directions: Productivity increased according to one study, but decreased according to the other. Both surveys asked questions about the businesses' perceptions of productivity changes and not actual measured changes; hence, the conclusions are subject to some uncertainty. It is also possible that the long-term effects of working from home are different, as factors such as knowledge dissemination may depend on working physically close to others. Effects through knowledge dissemination may not manifest themselves in the short run, but may become apparent over a longer time horizon.

Special consideration regarding the education and care of young children

In the case of schools and day care institutions, there may be an additional cost of lockdowns over and above the direct loss of production. The closure of these institutions may mean that a large number of children have to be cared for at home, which must be presumed to reduce the parents' effective supply of work.

Benefits of lockdowns: Less spread of infection

Two indicators of the potential for the spread of infection

The following are two indicators that shed light on the potential for the spread of infection in different industries and thus the benefits of business closures. The first indicator reflects the physical proximity to other employees. The second indicator shows the proportion of unique visitors to selected industries in the United States, which, under certain conditions, is also relevant to the spread of infection.

The indicators do not measure the actual spread of infection

In both cases, the indicators do not measure the actual spread of infection. The indicators are formed on the basis of information about and evaluations of the extent to which business activities are associated with situations that are expected to give rise to greater transmission of infection. Therefore, the indicators complement each other and together give a less uncertain picture of the potential spread of infection than if only a single indictor were used.

US indicator of employee proximity to other people

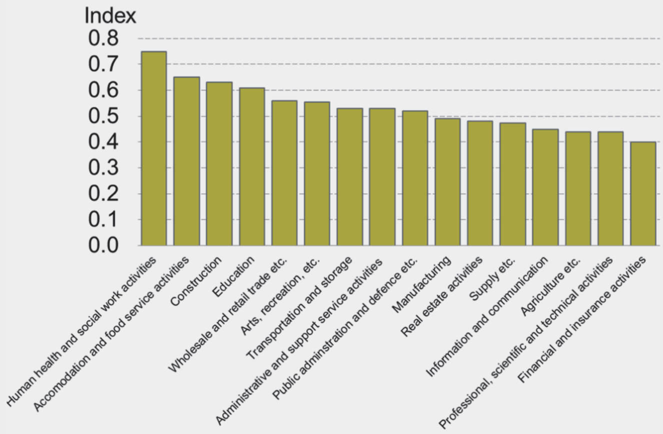
The first indicator of the spread of infection was based on a US survey that sheds light on the proximity of employees to other people in various jobs. These data have been translated to Danish conditions by using Danish data for the number of employees in various jobs at the industry level, cf. Box V.10.

Higher physical proximity for workers in personal service occupations

Employees in personal service occupations typically have a high degree of physical proximity to others in their work, which increases the potential for the spread of infection, cf. Figure V.14. Employees in industries with many office jobs typically have a lower degree of physical proximity to others.

FIGURE V.14 AVERAGE PHYSICAL CLOSENESS

The index for physical proximity for the average employee varies across industries and is typically highest in personal service occupations.



Notes.: The index is constructed using a US questionnaire survey that measures the extent to which different types of jobs are associated with physical proximity to other individuals.

Source: Own calculations based on data from Mongey et al. (2020) and register data.

Activities with many unique participants can lead to greater spread of infection

The spread of infection can also be affected by whether an activity has many participants who do not normally interact on a daily basis. This is because COVID-19 seems to be characterised by the fact that relatively few superspreaders account for a large proportion of the transmission, cf. Endo et al. (2020). This means that there can be a particularly large proportion of transmission associated with contact between people who do not normally interact on a daily basis, cf. Simonsen et al. (2020). If superspreaders only have repeated encounters with the same people (e.g., in a small workplace or at home), the virus will only be transmitted to a few people, as most people in the social circle are already infected and the same person cannot be infected twice within a short period of time. If, on the other hand, a superspreader meets many different people (e.g., in a public place), the potential for transmission is greater.[30]

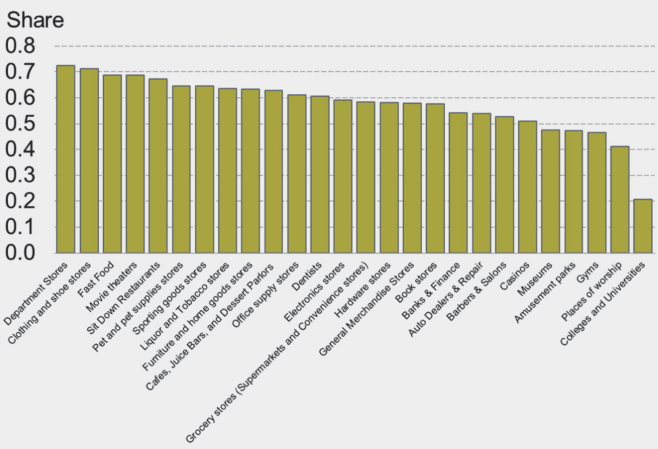
30) This effect applies to a lesser extent if the propensity to transmit the virus were more evenly distributed, i.e., the transmission is thus not driven by a few superspreaders. Here, the individual's propensity for infecting others will be so low that only a small

Difference in the proportion of unique visitors across industries

There is a large difference in the proportion of unique visitors across industries, cf. Figure V.15. At universities and religious institutions, for example, the proportion is relatively low, while in clothing stores and department stores, it is high. In interpreting the figure, it should take into account that the proportion of unique visitors is measured on the basis of mobile phone data from the USA in February 2020. It is possible that the numbers would look different for Denmark, and if the measurements were taken at other times of the year, the population's habits regarding leisure and work activities may be different.

FIGURE V.15 SHARE OF UNIQUE VISITORS, USA

The share of unique visitors vary across industries in USA.



Notes.: The share of unique visitors is based on GPS data from mobile phones.

Source: Own calculations based on Benzell et al. (2020).

proportion of the circle of acquaintances is infected. Therefore, the limiting effect from the fact that the same person can only be infected once over a short period of time does not occur. In other words, it is less important whether there are fewer repeated meetings with the same people, or whether there are fewer meetings with new people.

Alternative measurements of the transmission potential in industries with many visitors

For some service occupations, the transmission potential is not only determined by the physical proximity of the employees, but also by the customers' proximity. This applies to restaurants, shops, cultural institutions, educational institutions and other occupations, which involve people physically meeting for a longer or shorter period of time. In these cases, the transmission potential is, therefore, best illustrated by indicators that reflect whether the activity means that many people are close to each other for a long time. There are two alternative indicators of transmission potential, both of which take into account the degree to which employees and visitors are close to each other.

US measure of physical proximity of employees and customers in selected industries

The first alternative measure is calculated on the basis of GPS coordinates from mobile phones in the US, and primarily reflects how many people are gathered in a small space and for how long they are together, cf. Benzell et al. (2020).[31] In addition, the number of older visitors is taken into account (as the consequences of becoming infected for the elderly are greater) and the number of unique visitors (as more unique visitors involve greater mixing of different people and thus greater spread of infection). The target is based on GPS coordinates from US mobile phone users, which are used to track individuals' movements.

Danish indicator of transmission potential

The second alternative measure reflects the transmission potential across selected industries in Denmark and has been constructed by the Economic Experts Group on Re-opening of Denmark, cf. Andersen et al. (2020b). The indicator is generated from data on the number of visitors and the Danish Health Authority's assessment of how much transmission of infection the business activity in question entails. The analysis includes industries that were locked down in Denmark during the spring of 2020.

Differences in transmission potential relative to economic significance

In both the US and the Danish studies, the measure of the transmission of the infection is compared with various measures of economic significance in order to gain insight into which industries have a high infection rate relative to their economic importance. According to the two studies, fitness centres, sports shops, cafés, bars and pubs as well as leisure and youth activities are among the business activities that have relatively the greatest potential for transmission relative to their economic significance. Conversely, universities and colleges as well as banks and financial institutions are low in terms of transmission potential relative to economic significance. There is a big difference in which activities are included in the two studies, and both studies can thus be

31 The index reflects the total spread of infection in the industry and thus not the extent of infection for the average employee, as is the case with the proximity index above.

considered as a supplement to the other issues discussed in this section on the advantages and disadvantages of locking down different activities.[32]

Distribution and lockdowns

As mentioned above, it is also pertinent to consider the effects of lockdowns on income distribution. These effects should be viewed together with the possibilities for accessing aid packages and other distributional policies, such as transfer income.

Low-income groups are more vulnerable to lockdowns

People on low incomes are generally more vulnerable to lockdowns in the sense that they are less likely to work in jobs where working from home is possible, they more often work physically close to others, and they are less likely to work in an essential industry, cf. V.16. As it is more difficult for them to work from home, a lockdown will hit them harder in that they are more likely to lose their jobs in the absence of assistance packages and other measures. In addition, the probability that their industry is totally locked down is higher as, all else equal, they are more likely to work in non-essential industries doing jobs that are associated with greater physical proximity.

US study concludes that COVID-19 has led to layoffs of low-wage earners in particular

Chetty et al. (2020) examine the economic consequences of the COVID-19 pandemic in the United States and find that it is consumption that depends on physical interaction, such as hotel stays, restaurant visits and transportation, that had especially fallen, and this had led to a decline in employment in these industries. It is, to a larger extent, low-wage earners who had lost their jobs, as they are over-represented in hotels, restaurants and other occupations involving personal services. The results of the analysis may reflect both the effect of policy decisions on lockdowns and of reduced consumption for fear of becoming infected. In addition, the conclusions may be different in Denmark, as there are differences between the aid packages and other measures implemented in Denmark and those implemented in the USA.

Not clear-cut gender differences

The differences between men and women's vulnerability are generally smaller and not as clear cut as the differences between the highest and lowest income groups, cf. Figure V.17. On the one hand, women work more often in essential industries and in jobs where working from home is possible. On the other hand, the physical proximity to others

32) Eight of the same industries in the US study are included in the Danish study, and for these industries the ranking of transmission potential relative to economic significance is largely the same in the two studies.

is also greater for women on average. A virus outbreak can also affect the division of tasks in the household if children are home due to the closure of schools and childcare institutions. If it is primarily the women who look after the children at home while the men are at work, this can increase gender differences in the labour market and in the home, cf. Alon et al. (2020).

FIGURE V.16 INCOME

People with lower incomes have poorer opportunities to work from home, work closer to others and work less frequently in an essential industry.

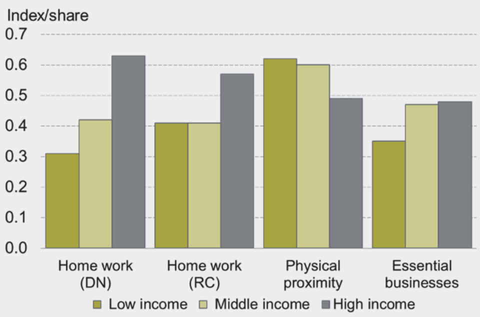
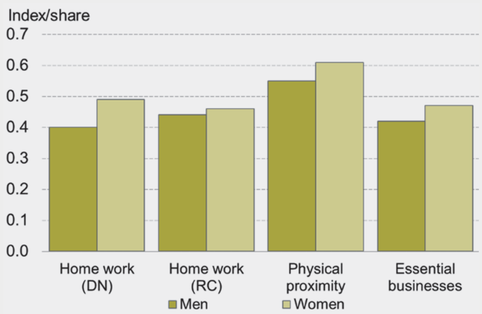


FIGURE V.17 GENDER

Women have better opportunities to work from home, work closer to others and more often in an essential industry.



Notes.: Low income indicates the group of employees that is below the first quartile in the income distribution, middle income is the group that is between the first and third quartiles, and high income is the group that is above the third quartile. Homework (DN) is index from Dingel and Neiman (2020) and Homework (RC) is the index from del Rio-Chanona et al. (2020). See Box V.10 for details on data.

Source: Own calculations based on Dingel and Neiman (2020), del Rio-Chanona et al. (2020)., Mongey et al. (2020) and register data.

TESTING AND QUARANTINE

Testing makes it possible to target restrictions on activities towards the infected

Widespread lockdowns affect both healthy and sick people and involve a major lockdown of production. Testing makes it possible to target the restriction of activities towards those who are infected, and may, therefore, involve lower economic costs than widespread lockdowns, cf. the discussion in section V.3. The benefits of testing must be weighed against the costs. It takes resources to perform and manage the tests, and it costs time for those who need to be tested.[33] Persons who test positive must also be quarantined, which also has associated costs. However, these costs must be seen in the light of the fact that targeted measures, if they are effective enough, can mean that widespread lockdowns can be avoided.

Effective use of testing is especially important if the strategy is suppression

Testing is an especially important instrument if a suppression strategy is pursued and the number of people infected is low. Here it is particularly advantageous to target the restrictions on activities towards the relatively few who are infected rather than to apply more general restrictions. For this to be possible, the use of testing and other measures must be so effective that the infection is kept in check until a vaccine or treatment becomes available. However, testing can also be important for a mitigation strategy - for example, to monitor how close society is to achieving herd immunity using antibody testing.

The Danish testing capacity is continually expanded

The number of weekly tests in Denmark has increased, and this has been made possible by a continual expansion of the testing capacity, cf. Figure V.18. The evolution in the number of people tested also reflects the level of infection in society - during August and September the number of infections increased, and this has been accompanied by an increase in the number of people being tested.

Several different ways to use testing

In the following, a number of different ways in which testing can be used to curb transmission are described. First, testing can be used to monitor the prevalence of COVID-19 in the population. This creates a better basis for implementing precise and cost-effective interventions aimed at the parts of the community where the infection is most prevalent. Another option is to carry out repeated tests of the entire population every few weeks and to isolate the infected. Finally, there are more targeted testing tools, where the tests are administered on people who are more likely to be infected (e.g., close contacts of infected people, returned travellers or employees in occupations with a high transmission potential) or on health professionals or others with a lot of contact with vulnerable people.

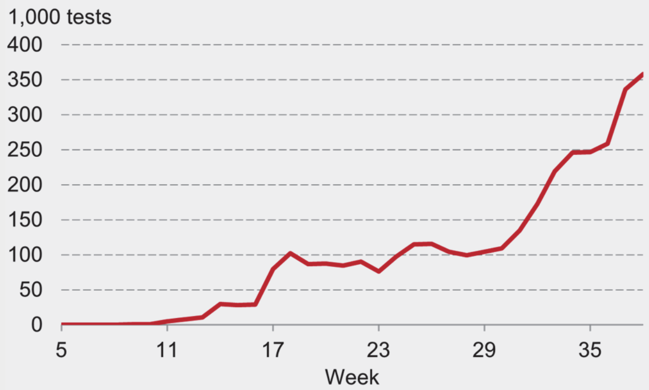
33) Another more indirect disadvantage is that the information about infection may, in principle, lead to more infection-transmitting behaviour, cf. Eichenbaum et al. (2020b). This can, in principle, occur because individuals are no longer afraid of becoming infected as they know they are already infected. If they are not encouraged to quarantine, the information that they are infected can lead to more infection-transmitting behaviour. However, this effect rests on the assumption that the behaviour is primarily driven by self-interest and that consideration has less importance. If moral considerations mean that consideration for others has the highest weight, individuals who test positive will choose to limit their infection-transmitting behaviour, thus eliminating the cost of testing.

Incentives to get tested and to quarantine

A common challenge for all testing measures is that they depend on the population's willingness to be tested and to quarantine. There are a number of measures that aim to influence the behaviour of the population in this regard, and these are discussed at the end of the section.

FIGURE V.18 NUMBER OF TESTS PER WEEK

The number of weekly tests has increased reflecting an increase in the test capacity.



Source: www.ssi.dk.

Monitoring the spread of infection in the community

Monitoring the infection to keep an eye on whether a strategy is working …

Monitoring the spread of the infection in the community is a prerequisite for pursuing any strategy, whether this is mitigation, suppression or containment. In terms of mitigation, it is necessary to keep an eye on whether the infection is rising towards a level where the capacity of the healthcare system would be challenged. Information about how many people have been infected also gives an idea of how far the population is from gaining herd immunity. With regard to containment and suppression, monitoring is relevant to ensure that the infection does not spread.

… and to be able to make effective interventions

Monitoring is also a prerequisite for ensuring that the right measures are introduced at the right time and targeted at the right parts of the community. For example, monitoring makes it possible to take action using geographically targeted measures to curb locally occurring outbreaks.

Information about those tested can be used to shed light on the trends in transmission of the infection

A part of the process of monitoring COVID-19 is carried out by the Statens Serum Institut, which collects information about who has been tested and whether the test was positive or negative. This information is used to monitor the trends in the prevalence across, among other things, age groups, gender, municipalities, industries and ancestry. A disadvantage of the method is that it is not a representative sample of the population that is tested, and that the incidence of infection among those tested, therefore, does not necessarily give a good picture of the incidence of infection in the population. As many of those tested are assumed to infected, the infection rate is therefore expected to be greater than the actual infection rate in the population. However, the number who test positive can be a useful indicator of the evolution of infection in the community, but account must be taken of whether there are major changes in the scope of testing or in the selection of those who are tested.

Random samples give a more accurate impression of the general level of infection if the participation and number infected is high enough

The spread of the infection can also be elucidated through random sampling, and this is done through the national prevalence study for covid-19.[34] In principle, the random sample will ensure that this is a representative sample of the population, and that the prevalence survey thus provides a picture of the actual level of infection. However, this presupposes that the participation rate in the sample is sufficiently high. In the latest round of the survey, 18,000 people received an invitation, and the participation rate seems to be between 30 and 40 percent, cf. Statens Serum Institut (2020c). A higher participation rate helps to provide a more accurate picture of the evolution in the epidemic in different parts of the country. Furthermore, a random survey provides a more accurate picture of the level of infection, the more widespread the infection is in the population.

Repeated tests of the entire population

In mass testing, the entire population is tested frequently

Mass testing involves testing to such an extent that the entire population can be tested, for example, every other week. The American economist Paul Romer is an advocate of this strategy, cf. Peto et al. (2020) and Taipale et al. (2020). The idea behind the strategy is to test the

34) The national prevalence study tests both whether the participants are infected with COVID-19 and whether they have been infected (a so-called antibody test). Thus, the study can be used both to monitor the current level of infection and to give an indication of how close the population is to achieving herd immunity, if immunity can be achieved.

entire population to detect and isolate a large proportion of those infected, thereby reducing the spread of infection. The effectiveness of the strategy depends on a number of factors.

Mass testing is effective if the testing and quarantine process is rapid and thorough

First, the effect will be greater if infected people are quarantined as soon as possible. The longer it takes from a person being infected to the person ending up in quarantine, the more people can be infected. Therefore, the effect depends on how often individuals are tested, the response times to getting the test results, and how quickly isolation takes place. Second, the effect of the strategy will be greater if the test and quarantine process is more thorough in the sense that more of those who test positive to COVID-19 end up being quarantined. This depends in part on the extent to which those selected to be tested actually take a test. It also depends on the test not misdiagnosing too many infected people as being healthy. Finally, it depends on the willingness of the individuals who test positive to be quarantined.

Mass testing requires a large capacity …

One possible challenge with mass testing is that it requires a large capacity and is expensive. If the entire Danish population were to be tested every two weeks, 2.9 million tests per week would have to be performed. In comparison, in week 38, almost 360,000 tests were performed. In other words, eight times as many people would need to be tested to achieve the goal to test everyone every two weeks. This would probably be a major challenge for testing capacity in Denmark unless new test types and procedures are introduced. In addition, there may be costs associated with isolation - especially if hotel rooms are made available to people who cannot safely isolate themselves in their own homes.[35]

… it is expensive but may be worth the price

Mass testing is, therefore, associated with significant costs. But if mass testing makes it possible to avoid general lockdowns of the economy, as occurred in the spring, it could be very worthwhile, and from an economic point of view, the willingness to pay would be high.

New, cheaper and faster tests make mass testing more attractive

New, cheaper and faster tests, which could make the mass testing strategy more attractive, are under development, cf. Taipale et al. (2020). Several of the new types of tests can also be used at home, which can make it less difficult to take the tests and increase the proportion of those selected who take the test. On the other hand, it may be more difficult for the authorities to monitor the results of home testing, and thus it is more difficult to monitor the spread of infection and

35) As a certain proportion of false positive tests can be expected when using mass testing, there will be a number of people who isolate themselves, even though they are not infected.

implement contact tracing and other measures that are required for the infected individuals to be identified by the authorities. Another important parameter of the new tests is reliability. The home tests that currently exist are often not approved by the authorities as they are judged to be too unreliable. Unreliability, of course, makes a test less attractive, but does not necessarily invalidate its applicability as part of a mass testing strategy. The precision of the test must be weighed against price, speed and other characteristics.

Contact tracing and other targeted testing

Detection is greatest when the tests target suspected infected people

When the tests are targeted at people who are suspected of being infected, all else being equal, more infected people are detected. Some degree of targeting can be achieved by testing people with symptoms. However, the effect of this test strategy on the spread of infection is limited by the fact that not all infected people have symptoms, cf. WHO (2020a). Some of these people can be detected by, for example, testing in districts, workplaces or schools where outbreaks have been detected.

Contact tracing can be an effective tool

In contact tracing, the testing targets people who have been in contact with infected people and, therefore, have a particularly high risk of being infected, cf. section V.3 and Alvarez et al. (2020). The effectiveness of contact tracing is determined by, among other things, the extent to which it is possible to trace a large proportion of the infected at a low cost. Thus, the effectiveness depends on several factors, such as how well-functioning and thorough the contact tracing unit is, the population's behaviour and willingness to cooperate as well as the possibilities for and acceptance of monitoring of the population. Contact tracing can serve as both an alternative and a supplement to locking down economic activities. Manual contact tracking takes place by calling the infected and their contacts by telephone; therefore, the cost per person must be expected to be non-negligible. If the number of infected people is high, it is, therefore, more expensive to carry out manual contact tracking if all the infected people and their contacts are to be contacted.

Speed is also important for effective contact tracing

Another important factor in the effectiveness of contact tracing is that potentially infected people are quickly traced, cf. Ferretti et al. (2020). If a large proportion of those who are infected do not have symptoms - either because they only develop them later in their illness, or because they do not develop them at all - it is important to trace and isolate them quickly before they have time to transmit the infection to others. This requires that they be traced shortly after they are infected. An element of rapid tracing is to streamline the work of contact tracing and ensure that there are enough resources allocated to it. Another element is to ensure rapid test results.

Limited monitoring of effectiveness of contact tracing in Denmark

To ensure that the chains of infection are broken, it is important that the contact tracing takes place as efficiently as possible, but there is currently only limited information about whether this is the case in Denmark, cf. Frøkjær (2020). Based on figures for June and July, the Danish Patient Safety Authority calculates that the contact tracing unit succeeds in contacting approximately 90 percent of those known to be infected. On average, the infected people contacted by the unit provide information on 4.5 close contacts. Out of these, the unit calls a third, and infected people are left to contact the others themselves. The relatively low proportion must be seen in light of the fact that there are also children among the close contacts, and infected people are typically responsible for contacting them themselves. There is no follow up on how many of the close contacts are being tested and how quickly this happens. Thus, it is not known whether tracing of some chains of infection stops because the infected do not get hold of all close contacts, or because some of the close contacts choose not to be tested. Overall, therefore, it is not possible to assess how effective contact tracing is in Denmark.

Sufficient resources for contact tracing can reduce the need for lockdown measures.

If there are enough resources for contact tracing so that it is sufficiently thorough and rapid, it can help to reduce the spread of infection, thus reducing the need for new lockdown measures. Contact tracing is labour-intensive; therefore, the effect of contact tracing will depend on whether it is sufficiently staffed. As long as the infection is at a relatively low level, the resources used to ensure that contact tracing is as effective as possible will probably be limited compared to the cost of a new general lockdown.

Contact tracing in Denmark is based on the infected doing the tracing to a greater extent than in Norway and Germany

Contact tracing in Denmark is based on infected people tracing their close contacts themselves to a greater extent than in Germany and Norway, cf. McGhie and Pedersen (2020), Fischer (2020) and the Folkehelseinstituttet (2020). In both Norway and Germany, it is the authorities who are responsible for obtaining the close contacts of the infected and following them up. In Denmark, it is, to a greater extent, the infected themselves who inform their close contacts that they may have been infected. During August and September, Germany and Norway had a relatively modest growth in the number of confirmed infected cases compared with Denmark.[36] A contact tracing system that is based to a lesser extent on the infected people informing their contacts themselves, means that more resources are used for tracing per in-

36) See, e.g., www.ourworldindata.org. The different trends cannot necessarily be attributed to the fact that Denmark has a different contact tracing system: there are many other possible explanations, such as differences in the development of testing capacities, differences in restrictions on business and coincidences.

fected person. However, if it also means that transmission of the infection is lower, it can mean lower expenditure on contact tracing and other infection-reducing measures in the long run. This summer, Germany set a target of one employee for contact tracing per 4,000 population, which corresponds to approximately nine times higher than Denmark's figure for August, cf. McGhie and Pedersen (2020).[37]

Infection warning notification app as a supplement to contact tracing

An app for mobile phones that indicates whether the user has been in the vicinity of people who are found to be infected can be a useful supplement to contact tracing. One of the advantages of an app may be that it is faster than traditional contact tracing, cf. Ferretti et al. (2020). Another advantage is that the app also picks up contacts that the infected person does not know, whereas traditional contact tracing typically picks up largely only known contacts and not, for example, people who have been close to the infected person on a train or in a restaurant.

The effectiveness depends on the number of users, measurement capability and the behaviour of the population

The effectiveness of the app depends squarely on the number of users, cf. Barrat et al. (2020). This is because the app only works when two people meeting each other both have the app. This can present a challenge as concerns about being monitored may deter some people from downloading and activating the app. The effectiveness also depends on the app's ability to measure whether two people are close to each other. Leith and Farrell (2020) question whether the Bluetooth technology used is well-suited for this purpose. Based on various experiments, the authors conclude that the signal strength used to determine whether two people are close to each other depends on which way the phone is directed, as well as the physical environment in the form of people, buildings and means of transport. Finally, the impact of the app, as with the other testing strategies, depends on the willingness of the population to get tested and to quarantine.

The Danish app has probably had a modest effect so far

The Danish app, smitte|stop (infection |stop), has probably had a modest effect on the transmission of infection so far, cf. the Ministry of Health and the Elderly (2020). The effect of the app can be illustrated by using the Statens Serum Institut's ongoing survey of Danes who book an appointment for a COVID-19 test at coronaprover.dk. The survey response rate is approximately 58 percent. Over the period from July 6 to September 11, 586 people indicated that they booked an appointment for a COVID-19 test because they had been notified by the app that they had been in the vicinity of an infected person. Out of

37) However, these figures must be seen in the light of the fact that staffing has subsequently been scaled up in Denmark, and that it is now possible to draw on resources from other parts of the public sector, including the operational staff in the Danish Police, cf. Elkorn (2020).

these, 478 people indicated that the app was the only reason for booking a test. Out of the 478 people, 8 people subsequently tested positive for COVID-19. If the survey is representative and reasonably reliable, the app has resulted in approximately 14 people testing positive following booking a test on coronaprover.dk. This is a low number, compared to the 7,100 plus who tested positive during the survey period. However, the figure must be seen in the light of the fact that not everyone tested in Denmark books a test via coronaprover.dk. For example, it is also possible to be tested without an appointment at border crossings and mobile test centres. It is thus possible that notifications from the app have resulted in more infected people being detected via tests that were not arranged via coronaprover.dk.

Potential for improving the app's impact

The impact of the app will be greater if more people use it. It is not possible to calculate how many people actively use it, as no data is collected about the individual users for confidentiality reasons. At the end of September 2020, however, the app had been downloaded approximately 1.4 million times, which means that less than 25 percent of the population use it. Thus, there is potential for an increase in the number of users and thus an improvement in its impact. Another potential may lie in examining the app's functionality through, for example, questionnaires or experiments, which can reveal whether the app needs coding adjustments. One last option is to mandate that people who participate in activities with high transmission potential have with them a mobile phone with an activated on-the-spot infection tracing app.

Testing of travellers arriving from areas with high infection rates

Tests can also be targeted at travellers arriving from areas and countries where the number of infections is high. This can be done, for example, by having test facilities at airports and border crossings and isolating the arrivals until a test result is available. Another option is to require arrivals to present a negative test that has been performed recently.

Incentives for testing and quarantine

The willingness of the population to test and isolate is important

The willingness of the population to be tested and to quarantine if infected is a key element of any testing strategy. This applies regardless of whether it is a matter of mass testing, contact tracing or other strategies.

Cash payments or penalties to encourage testing

To the extent that the recommendations for testing are not followed, subsidies or other regulations may encourage this. One option is to give a cash payment to those who turn up for testing. The cost of this solution obviously depends on the number of tests. In the case of contact tracing and representative sampling, it is not necessarily an expensive solution. Another option is sanctions for those who do not turn up to be tested.

Easy and rapid process can encourage testing

The incentive to be tested can also be increased by ensuring that it is easy, free and fast to be tested and get the results. In Denmark it is free for everyone to book a COVID-19 test, but the hassle of being tested can hold some people back. To reduce the hassle, you can, e.g., make sure that the booking process is easy, and that there is a good selection of available times and a good geographical coverage of test sites and short waiting times for results after the test. As mentioned above, a reduction in the waiting time before and after testing will also mean that infected people are found more quickly and, thus, isolated to a greater extent before they have time to infect others.

Increased reliability as a result of multiple tests can encourage testing and quarantine

Another option is to offer multiple independent tests to the same individuals to increase reliability and reduce unnecessary quarantine. This is primarily effective in the case of more uncertain tests. Increased reliability can both make it more acceptable to be tested and make it more acceptable to be quarantined.

Compensation for the costs of quarantine

There are several options for encouraging quarantine by compensating for the cost of being in isolation. First, housing and hotel rooms can be made available to people who cannot isolate safely and away from other household members in their own homes. This can apply, for example, to families that have many people living in a small space. In Denmark, those who cannot isolate in their own home can be referred by their municipality to external isolation accommodation based on a number of isolation and target group criteria, cf. the Danish Health and Medicines Authority (2020). Second, legislation and support schemes can ensure that infected people who are unable to work do not lose their jobs or otherwise suffer a financial loss. This can be particularly relevant for people working part-time and other employees whose salaries depend directly on the number of hours worked.

Isolation of the infected is essential, but whether it is adhered to with is not known

An essential element of any testing strategy is that the infected are isolated. Before 12 March, infected people and their households were quarantined in their own homes and contacted daily by the authorities to follow up on whether the quarantine directions were being complied with, cf. the Danish Agency for Patient Safety (2020). As of 12 March, this practice was abandoned based on the argument that Denmark had moved away from using a containment strategy. Therefore, there is limited information about the extent to which infected people are actually quarantining. A Norwegian survey indicates that not everyone follows the authorities' requests to quarantine, cf. Steens et al. (2020).

Consequences for privacy of more surveillance

Increased monitoring of the behaviour of infected and potentially infected people may have undesirable consequences for privacy. These are costs that must also be weighed against the benefits of increased monitoring in the form of a better level of information. Another possible benefit of increased monitoring is that the information can be used to sanction individuals who do not comply with the guidelines on testing and isolation. Such sanctions may provide benefits in the form of a reduction in the spread of infection, but may be undesirable for moral and ethical reasons.

OTHER MEASURES

Shielding of vulnerable groups

A possible variant of a mitigation strategy is to shield vulnerable groups and allow the infection to spread in the rest of society, cf. Acemoglu et al. (2020). This strategy is appropriate if the following conditions are met. First, the protective shield must be sufficiently tight. If a large proportion of the population is infected, it can be difficult to prevent the infection from spreading to the vulnerable. For example, there is a risk that staff in nursing homes and hospitals become infected, and it can also be difficult to isolate vulnerable people living in their own homes to a-sufficient degree. Second, the disease must not have excessive health costs for the rest of the population. Third, the welfare loss for the vulnerable due to the fact that they may have less contact with family and friends should not be too great. The welfare costs of shielding can be particularly high if lasting immunity is not achieved after infection. In this case, the infection will flare up again from time to time, cf. section V.2; therefore, it will be necessary to shield the vulnerable until a vaccine or treatment is available.

Dissemination of information on the numbers infected

Information about how widespread a disease is can affect behaviour and thus the spread of infection. A US study thus concludes that population mobility is affected by official infection rates, cf. Engle et al. (2020). The study measures population mobility in US counties based on GPS data from mobile phones. This is compared with the development in official infection rates at the county level. There is a negative correlation between mobility and infection rates, even when taking into account whether a lockdown has been implemented in the county in question, suggesting that information on the spread of infection has a direct effect on behaviour. However, this conclusion must be seen in light of the fact that no account is taken of other policy measures that may affect mobility - for example, lockdown of business activities. In Denmark, information on the number of infected over time and disaggregated by municipality is available on the Statens Serum Institut's website and in the news media, which makes it possible for the population to react to local outbreaks.

Information about and encouragement of transmission-reducing behaviour

It is also possible to influence behaviour and the spread of infection through information about how to avoid being infected and advice to the population. A survey showed that 20 percent of the employees in the private manufacturing sector worked from home in the middle of March, cf. Danish Industry (2020). The manufacturing sector was not closed down by law, but the authorities encouraged employees in all private enterprises to work from home to the greatest possible extent. It is difficult to quantify the effect of advice on and information about other infection-reducing behaviours, such as proper use of masks, frequent hand washing and physical distancing from other people. In most cases, the cost of disseminating information is limited. However, if the advice is followed, the changed behaviour may have costs for the individual (for example, the hassle of washing hands or using a mask). These costs must be weighed against the benefits in the form of lower transmission.

Capacity building can help deal with future epidemics, …

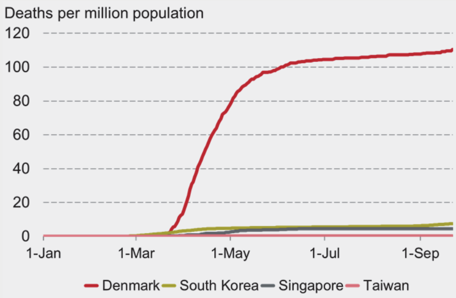
Building institutional capacity can help reduce the consequences of future epidemics. Pardo et al. (2020) argue that a number of East Asian countries have done well through the COVID-19 pandemic because they learnt lessons from previous epidemics (SARS, MERS and H1N1) and, therefore, built institutional capacity in three areas. First, they have had the necessary legislation in place to enable them to respond quickly. Second, they had built up a health system that can detect and fight the spread of new diseases and has the capacity to manage infections. Third, they have used technology for contact tracing, quarantine enforcement, information dissemination, and to monitoring the spread of infection.

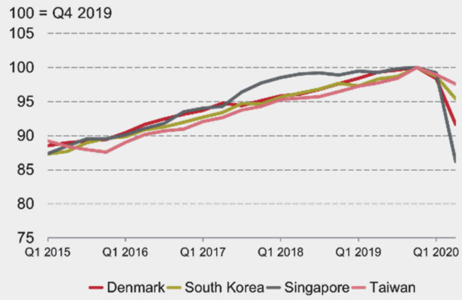
… but is no guarantee of avoiding lockdowns and deaths

However, institutional capacity is not a guarantee of coping with the COVID-19 pandemic without lockdowns and the associated economic consequences, cf. Figure V.19. South Korea, Singapore and Taiwan have fewer deaths of people with COVID-19 per capita than Denmark. South Korea and Taiwan have also experienced a smaller decline in GDP than Denmark, according to preliminary figures for the first half of 2020. But Singapore has experienced a sharper decline in GDP than Denmark, which must be seen in light of the fact that large parts of the economy were in lockdown for an extended period in the spring. There can be many explanations for the differences in the number of deaths of people with COVID-19 and GDP in the four countries considered (e.g., differences in statistical methods, age composition of the population, occupational structure and culture), and it is, therefore, not possible to draw conclusions about an actual causal relationship on the basis of the observed trends. To work out the extent to which institutional capacity can explain the differences requires, therefore, a closer examination of, for example, how infection tracing, use of technology, quarantine enforcement and other measures have contributed to reducing transmission in the countries considered.

FIGURE V.19 DEATHS AND GDP IN EAST ASIAN COUNTIRES AND DENMARK

The number of people death with COVID-19 per million population is significantly lower in the East Asian countries, which have recent experience of dealing with other epidemics. All three countries have however been hit by a decline in GDP in first half of 2020.





Notes: There may be differences in definitions across countries.

Source: Statistics Denmark, National Accounts, Ourworldindata.org and Macrobond.

SUMMARY

The prioritisation of measures based on transmission effects, cost, distribution and uncertainty

There are a number of instruments available which have different effects on the spread of COVID-19 and different costs. The effect on the transmission of infection must be weighed against the costs when prioritising which instruments are to be used to pursue a given strategy. Uncertainty must also be taken into account, which is a particular challenge in the case of a new and unknown virus. In addition, distributional effects must be taken into account.

Effective to lockdown activities where many are in close proximity for long periods

Lockdowns of infection-transmitting activities seem to be an effective tool, but also have costs. The effect on the spread of infection depends on the nature of the activity: In activities that involve many people standing close together for a long time, a large effect on transmission would be expected if the activities are locked down. The reverse is true of activities where few people gather and where it is possible to keep a physical distance.

Lockdowns reduce welfare

Banning activities has welfare consequences. In the case of business activities, the costs can be calculated on the basis of the decline in production in the locked down activity and flow-on effects to other parts of the economy. In the case of leisure activities, it is more difficult to calculate the cost of lockdowns, as the benefits of the activities are not traded in a market and, therefore, do not have a market price that can be used to value them.

Costs of locking down businesses depend on the effect on output

In the case of business activities, three indicators that shed light on the decline in production and thus the cost of lockdowns for different industries are considered. First, a large value added indicates that there will be a large direct production loss associated with locking down the activity. Second, some goods and services are so important and difficult to replace, that they can be said to be essential to society. Third, the ability to work from home can significantly reduce production losses from lockdowns of physical workplaces.

High direct costs of general lockdowns

General lockdowns, where a large proportion of business activity is restricted, can have high direct costs. However, the cost of locking down must be seen in the light of what the alternative is. In some cases, it may be less costly to lockdown today than to wait and risk a larger and more expensive lockdown in the future. Under a containment or suppression strategy where the number of infected people is low, it will probably be less costly if the effective reproduction number can be kept below 1 using more targeted measures. As far as more limited restrictions are concerned, there may be a few activities that have such a large potential for transmission that it is necessary to keep them closed for a longer period if the infection is to be kept in check.

Testing makes it possible to target restrictions at the infected

Another category of measures involves testing whether individuals are or have been infected with the virus. Testing makes it possible to isolate those who are infected to prevent transmission of the infection. Quarantine can be considered to be a kind of targeted lockdown, where the restrictions on activities only affects those who test positive. Therefore, in the case where there are only a few who have tested positive, the cost of quarantine will typically be less than the cost of wider lockdowns. Testing and quarantine can be used in several different ways.

Mass testing is effective under certain conditions but requires inexpensive tests

In mass testing, the entire population is tested repeatedly at a fixed time interval. Mass testing can be so effective under certain conditions that transmission of the infection stops completely. Efficiency is increased if the tests are accurate, the time interval is short and if the population complies well enough with the authorities' requirements regarding tests. Mass testing is more attractive if the cost per test is low. New, inexpensive types of tests that can be done at home can help make mass testing less costly.

Effective contact tracing can reduce the need for expensive lockdowns during suppression

Another testing instrument is contact tracing, where close contacts of infected people are tested to detect and eliminate chains of infection. Here, testing is targeted at people who are assumed to be potentially infected, whereby more infected people are found than if the same number of tests had been performed on random people. Thus, the instrument can be used to find and isolate infected people during a containment or suppression strategy where the level of infection is low. If contact tracing is effective, the need for major lockdowns during a suppression strategy is reduced. Contact tracing is most effective if the testing and isolation process is rapid, so that infected people are isolated before they have time to pass on the disease. Another important factor is that the tracing process needs to be sufficiently accurate to identify the individuals who have actually been in close contact with infected people.

The effect of Danish contact tracing is not clear due to lack of monitoring

The impact of the Danish contact tracing unit is not clear. This is partly due to the fact that there is no monitoring of how many of the close contacts who are contacted by the health authorities and asked to take a test actually do so, and how many of the group subsequently test positive. There is also no monitoring of how many infected people are quarantined. The lack of registration and monitoring of contacts must be seen in the light of privacy concerns.

Probably modest effect of Danish app so far

The cost of manually tracing close contacts will typically be high if a large number of potentially infected people need to be contacted. Manual contact tracing can be supplemented with an app that makes the cost of contacting the close contacts of those who test positive lower. The app can also have the advantage that it can detect potentially infected people who are not captured by manual contact tracing, for example, people who are not in an infected individual's circle of acquaintances, but who have nevertheless been close to the infected person. It seems that the Danish app for infection detection has thus far led to a modest reduction in the spread of infection.

Encouraging testing and quarantine makes testing strategies more successful

A common denominator for the different types of testing strategies is that they are more successful if the population is willing to be tested and to subsequently quarantine. The incentives for testing and quarantining can be influenced in several ways: Costs can be reduced (for example, by making hotel rooms available for free); the benefits can be increased (for example, by giving cash payments to people who get be tested); and sanctions can be imposed on those who do not follow the directives.

V.6 SUMMARY AND RECOMMENDATIONS

Virus outbreaks have significant health and economic consequences

The outbreak of COVID-19 has hit the world community hard in 2020. During the late summer, there has been a marked increase in the number of people infected with COVID-19 in Denmark and an increase in the number hospitalised. The outbreak of COVID-19 has significant health and economic consequences for society. In this chapter, the focus has been on the interrelationship between epidemiology and economics. The discussions in the chapter are relevant for both the remainder of the current epidemic and for future similar virus outbreaks.

Significant cost of lower economic activity

The outbreak of a virus in itself causes a significant decrease in economic activity, partly because households are reluctant to consume in order to avoid becoming infected. This is especially true for industries where it is difficult to avoid contact with other people. A period of low economic activity has a number of costs to society. In addition to the fact that the loss of production by itself leads to a welfare loss, lower economic activity will lead to increased unemployment and a loss of income for people in the affected industries and there is the risk that this will lead to long-term unemployment. There is also a risk that business lockdowns will result in the loss of company-specific institutional knowledge, which may reduce productivity in the long run. At present, it is difficult to assess what form and to what extent the structural effects will take. Among other things, it will depend on how long the health crisis lasts.

Some measures that limit the spread of infection also reduce economic activity

In Denmark, as in most other countries, restrictions and measures have been introduced with the purpose of limiting the spread of COVID-19. However, while such measures will reduce the spread of infection, they will also amplify the decline in economic activity. The Government and the Danish Parliament have sought to compensate for the financial consequences of the restrictions by introducing various types of aid packages.[38]

Three strategy types: containment, suppression, and mitigation

Three main types of strategies can be distinguished to counter a virus outbreak in society. A containment strategy aims to eradicate the virus. A strict containment strategy has proven difficult in relation with COVID-19, partly because a large proportion of those infected do not show symptoms and because the infection is imported from other countries. If containment is not possible or is too costly, the spread of infection can be limited through a suppression strategy. In contrast to containment, the aim is not to eradicate the virus, but to keep it at a low level, for example, until a vaccine becomes available. Finally, it is possible to use a mitigation strategy where the virus spreads widely in the community but in a controlled way to limit the health costs of the outbreak, such as overloading the healthcare system. Under a mitigation strategy, a larger number of infected people is implicitly accepted, which may have the advantage that, over time, herd immunity is built up in the population - if immunity is achieved after infection.

In some cases, containment or suppression may be appropriate, …

It is not clear whether containment, suppression or mitigation is the most appropriate strategy for tackling the COVID-19. This depends, among other things, on a number of epidemiological and economic factors, about which there is considerable uncertainty so far. Suppression or containment may be appropriate if the virus has a high mortality rate and if, for example, a vaccine is expected within a shorter period of time. The uncertainty as to whether COVID-19 causes long-term health effects also speaks in favour of caution and adopting a strategy in which infection is suppressed or contained. This, in turn, may require extensive testing capacity (to identify the infected), tight controls over the transmission of infection from abroad, effective contact tracing and periodic lockdowns of parts of the economy. All of these elements can involve significant costs to society.

… while in other cases, mitigation may be appropriate

In certain circumstances it may be appropriate instead to rely on a controlled transmission strategy. If recovered people develop antibodies that protect against new infection by the same virus for a longer period of time, such a strategy will result in herd immunity being acquired in the community over time as a result of a sufficient number of people being infected. Thus, for that reason alone, the number of current infected will decrease sooner or later. However, the benefit of a controlled spread is lower if individuals who have been infected are only immune to the virus for a short period of time. The mitigation strategy

38) These assistance packages are discussed in more detail in Chapter I of De Økonomiske Råds formandskab (2020) (in Danish).

becomes more favourable relative to suppression if, for example, it is possible to shield vulnerable groups from infection, if there is no prospect of a vaccine and if it is difficult to avoid the transmission of infection from abroad.

Under a mitigation strategy, it may be appropriate to try to reduce overshooting

If an attempt is made to achieve herd immunity via the controlled spread of infection, it is expedient to try to reduce the degree of overshooting, i.e., to try to prevent the final number of infected people exceeding the number required to achieve herd immunity in the absence of a vaccine. Thereby, the number of deaths due to the virus is reduced. In order to reduce overshooting, measures that slow the spread of infection over a prolonged period of time and that can be adjusted up and down as the number of infected people increases and decreases are needed. This also helps to reduce the risk of the healthcare system reaching its capacity limit.

The Danish strategy is a "hammer and dance" strategy

At the beginning of the epidemic, the Danish authorities tried to contain the epidemic. Then there was a shift to a strategy with the character of mitigation and later to a strategy of suppression in the form of the so-called "hammer and dance". The hammer is made up of the lockdown at the beginning of the outbreak, which was intended to knock the infection down. The dance is the current phase, where, ideally, minor outbreaks are managed by targeted measures, such as contact tracing and local restrictions.

Measures should be chosen such that they achieve the strategy at the least possible cost to society, …

Whatever the strategy, infection control measures should be applied such that the strategy is pursued at as low a socio-economic cost as possible. Therefore, the measures that reduce the infection a lot relative to what they cost society should be introduced first. Conversely, measures that have a small effect on the infection relative to what they cost society should be used last or not at all.

… taking into account effects on uncertainty and distribution

In selecting the most appropriate strategies and instruments, distributional effects and uncertainty should be taken into account. Distribution effects can occur in connection with, e.g., lockdown measures as these can have disproportionate effects because low-income employees often have jobs that are difficult to perform from home. Uncertainty can, for example, be relevant to considerate because instruments that, with a high probability, can limit transmission, all else equal, are preferred to instruments where there is greater uncertainty about their effects.

Under suppression, targeted measures are preferable to general lockdowns

In the current situation, where the strategy is "hammer and dance", targeted measures will be preferable to a major lockdown, which is a very expensive solution. Examples of targeted measures are contact tracing and local measures in areas where transmission of the infection is particularly high. Such a targeted measure could also be a ban on activities with a particularly high potential for transmission, such as large concerts and other so-called superspreading events. Such measures are preferable to larger lockdowns like the one introduced in March.

Essential activities should be designated in general lockdowns

If the current strategy of suppression is maintained, a large-scale lockdown may nevertheless become a necessity. In this case, there should be a clear political priority in advance, taking into account that regional conditions and industry structures may have a bearing on the trade-offs. The starting point for this prioritisation must be to identify the activities that are of a so-called essential nature and that, therefore, are not appropriate to lock down. It is ultimately a policy trade-off, but in addition to the health sector, it could include infrastructure, the food industry, police, military and the justice system.

Several criteria should be considered when deciding which activities to lock down

Lockdowns should, of course, be imposed on activities that cannot be deemed to be essential. Among these, different factors must be weighed against each other: How much do the respective activities contribute to the spread of infection, to what extent is it possible to carry out the work from home, how much value is created in the relevant industries, and who is affected by restrictions imposed on the respective activities?

The government should clearly state possible scenarios

A new general lockdown would in itself be costly while it is lasting, and at the same time, the increased uncertainty for business and households may lead to more restrained behaviour in terms of investment and consumption. A lower level of investment will ultimately reduce the long-term level of prosperity. Therefore, the government should state clearly what initiatives it intends to implement if the recent increase in the number of infected people continues or increases. The ability of businesses to plan and make decisions is strengthened if they know the likely scenarios in the case that the infection gets out of control. The alternative is a situation where they neither know the likelihood nor the consequence of such a case. Such a conditional plan exists, for example, in New Zealand.

It is expensive to test widely, but the savings can be significant

With a strategy such as the Danish one, it is appropriate to have a significant test and contact tracing capacity to identify those who are infected. While major economic lockdowns affect both the healthy and those who are infected, tests and quarantine measures allow for targeted restrictions on the infected. Likewise, tests can reveal whether there is a particularly high level of infection and thus a special need to put targeted measures in place to help specific geographical areas, occupations, educational or population groups. There are, of course, a number of costs associated with testing, contact tracing and ensuring compliance with quarantine measures. For example, it requires resources to detect potential infections and to perform and administer the tests. However, there can be significant benefits for society from tracing potential infections, making testing capacity available to the population and introducing quarantine measures for those who test positive, rather than imposing major lockdowns of economic activity. This justifies a comprehensive testing and contact tracing capacity.

Mass testing can, in principle, slow down transmission, but requires, among other things, testing on a large scale

There are several testing instruments that can be used to fight transmission of the infection. The American economist Paul Romer has recommended the use of mass testing, where the entire population is tested approximately every two weeks. This strategy can, in principle, ensure that the vast majority of infections are detected; thus, keeping the reproduction number below 1 and containing the virus. However, it requires that a number of prerequisites are met. First, the population must be willing to be tested and those who test positive must be willing to be quarantined. Second, the tests must be sufficiently accurate so that there are not too many infected people who falsely test negative. Third, the test frequency must be sufficiently high. In addition, a suitable and practicable mass testing strategy requires the availability of testing technology that allows a very large number of tests to be performed.

Mass testing should be considered if inexpensive home testing becomes a reality

Mass testing should be considered if sufficiently reliable types of testing become available that can be performed on a large scale. There are several new tests under development that can be performed at home without the use of significant laboratory capacity, and which will probably be significantly cheaper to produce than the existing tests. A challenge with these tests is that they are less reliable than existing tests, which, however, does not necessarily invalidate the effectiveness of mass testing.[39] If tests are performed at home, another challenge may be that it becomes more of the individual's responsibility to perform the tests correctly and at the specified time.

39) The disadvantage of false negative testing is that some infected people are not detected, and thus pass the infection on. However, this disadvantage can possibly be reduced by increasing the test frequency to catch those who were not originally picked up. The downside of a false positive test is that people have to quarantine even though they are not actually infected. It can also have the consequence that people who have received a false positive test subsequently fail to exercise caution in their behaviour because they mistakenly believe that they are immune. These problems can be reduced by having those who test positive take an additional test to increase the reliability of the test results.

Contact tracing can theoretically slow down the infection if it can be done effectively enough

Contact tracing is a more targeted testing strategy that involves unravelling chains of transmission by tracing and testing close contacts of infected people. This strategy can theoretically slow down transmission and ensure that the virus can be contained, but it requires that a number of preconditions can be met: The contact tracing must be thorough, i.e., a sufficiently high proportion of those who have been in contact with an infected person must be contacted; the process must be rapid enough so that any infected contacts do not have time to pass on the infection before they are traced and; the introduction of infection from abroad must not be too extensive, as infected people arriving from abroad will not be known to the contact tracing unit. Finally, the instrument requires that a sufficiently high proportion of those who are infected go into quarantine.

Monitoring contact tracing and ensuring that it is effective is essential

There is no clear picture of how effective contact tracing is in Denmark. This is partly due to the fact that there is no monitoring of the outcomes of the contact tracers' contacts with the infected. That is, there is no information about whether the traced close contacts actually get tested, and if so, how quickly they get tested, whether they test positive or whether they subsequently self-isolate. With the choice of suppression as a strategy, it is essential to be able to continually evaluate how effective the contact tracing is.

Monitoring contact tracing enables efficient resource use

Ideally, thorough monitoring could identify what proportion of the newly infected can be traced to an already known outbreak and how large a proportion of the transmission of the infection has arisen from an unknown source of infection. A thorough monitoring of how effective the contact tracing is will make it possible to deploy more resources or make changes in workflows and processes if it turns out that there is a need to make the contact tracing more effective. Increased surveillance of the infected through contact tracing must be weighed against considerations of privacy. One can, however, imagine a mild version, where the contact tracing unit follows up on the contacts to find out whether they have subsequently been tested and whether there is a need to trace their close contacts to reach a link further out in the chain of infection.

Willingness to pay to avoid a new lockdown can be high

Extensive lockdowns are costly to society, but can be an emergency solution if the spread of infection increases and there is a desire to suppress the virus. However, as major lockdowns involve significant socio-economic costs, it may be appropriate to spend a lot of resources on contact tracing and other measures if this can mean that the spread of infection can be kept down without the use of a new lockdown.

Comparison of contact tracing with other countries in order to follow best practice

It is appropriate to compare the Danish measures with the contact tracing measures in other countries to ensure that best practice is followed. An investigation of whether there are differences in workflows and resource use, and whether these factors can contribute to explaining any differences in the effect of contact tracing can be an important step in the direction of improving the efficiency of the Danish contract tracing system.

Testing of representative samples may be appropriate

With a strategy where the focus is on the controlled spread of infection, it is appropriate to be able to continually monitor where society is at in the process. Therefore, it is necessary to carry out testing of representative samples in order to determine what proportion of the population is infected and how many have developed antibodies to the virus. Testing of representative samples can also be used to learn more about the nature of the disease - including the extent of asymptomatic infection, long-term health effects, and information about how the virus is transmitted. That information can contribute to better management of the epidemic, even in the current situation where the strategy is suppression. In Denmark, the authorities have tested randomly selected samples of the population, but less than half of those invited to take a test actually turned up for the test in the latest round, which means that the study's test results are not as representative as they could be.

Relevant to consider whether there should be better incentives to participate in testing …

Whether testing for the purpose of monitoring the level of infection or for finding and isolating infected people, it is essential to ensure that there is as much participation as possible. In the case of representative sample testing, there may be several reasons why some of the people invited to participate do not participate. One possible explanation is forgetfulness; therefore, it is important to make sure that sufficient reminders are given to participate in the study. Another possible explanation is that those who are invited to participate do not find it worth the effort to do so. In this case, it may be appropriate to increase their willingness by using financial incentives. This can be done, for example, in the form of a cash payment for participating in the test. Alternatively, sanctions may be imposed on those who do not turn up. If the lack of participation is instead due to actual opposition to being tested, it could be difficult to increase participation through reminders, financial incentives or sanctions. Instead, in this case, consideration should be given to increasing the number of people invited to participate in the test. Regarding the use of testing in general (and therefore not only for representative sample testing), whether the difficulty or inconvenience of being tested could be reduced should be considered, for example, by ensuring that there are geographically widespread and sufficiently many test centres and that there are no long waiting times to be tested and to get the subsequent test result.

… and to go into quarantine

A key element in all strategies aimed at limiting transmission is that the infected are isolated. Therefore, it is also relevant to consider whether there are the right incentives to go into quarantine. The cost of quarantining can, for example, be reduced by making hotel facilities available to infected people who do not have the possibility to adequately self-isolate at home.

Preparedness can be insurance against future epidemics

History shows that pandemics occur from time to time. While they are relatively rare, they can have significant health and economic consequences. Therefore, it is appropriate to consider whether there is an adequate level of preparedness in the event of a future pandemic. Pandemic preparedness plans may include monitoring potential outbreak threats and continually updating the plans accordingly. A preparedness plan should be prepared according to global best practice and potentially enable a virus outbreak to be contained early, for example, through effective contact tracing, testing and control of arrivals from abroad, so that major lockdowns can be avoided. A well-functioning pandemic preparedness plan can thus act as insurance against future pandemics.

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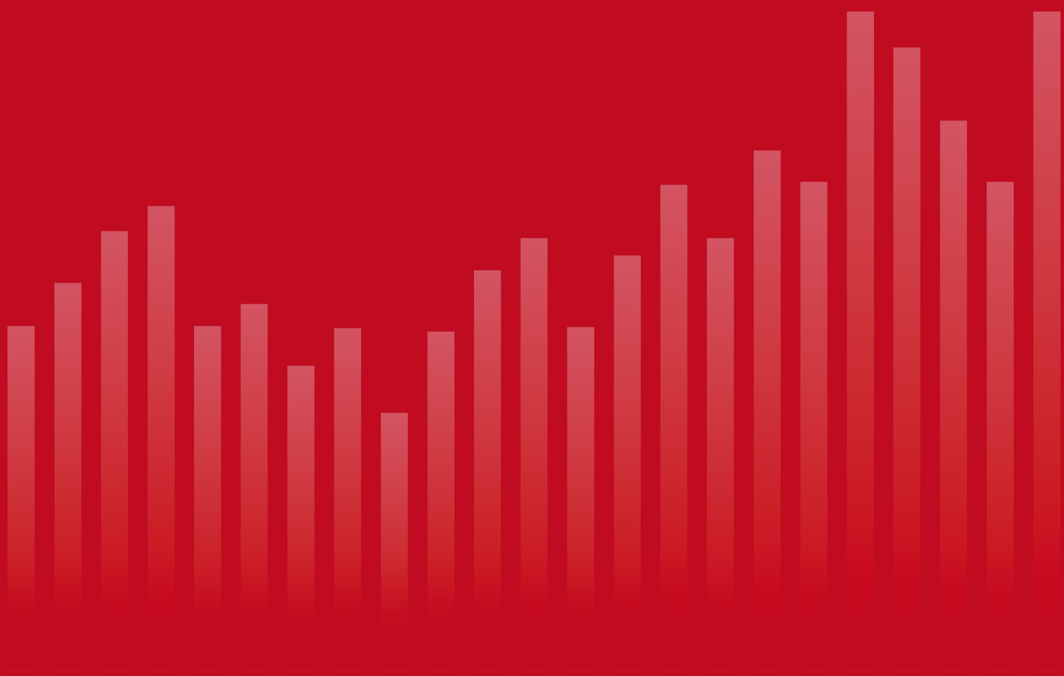

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