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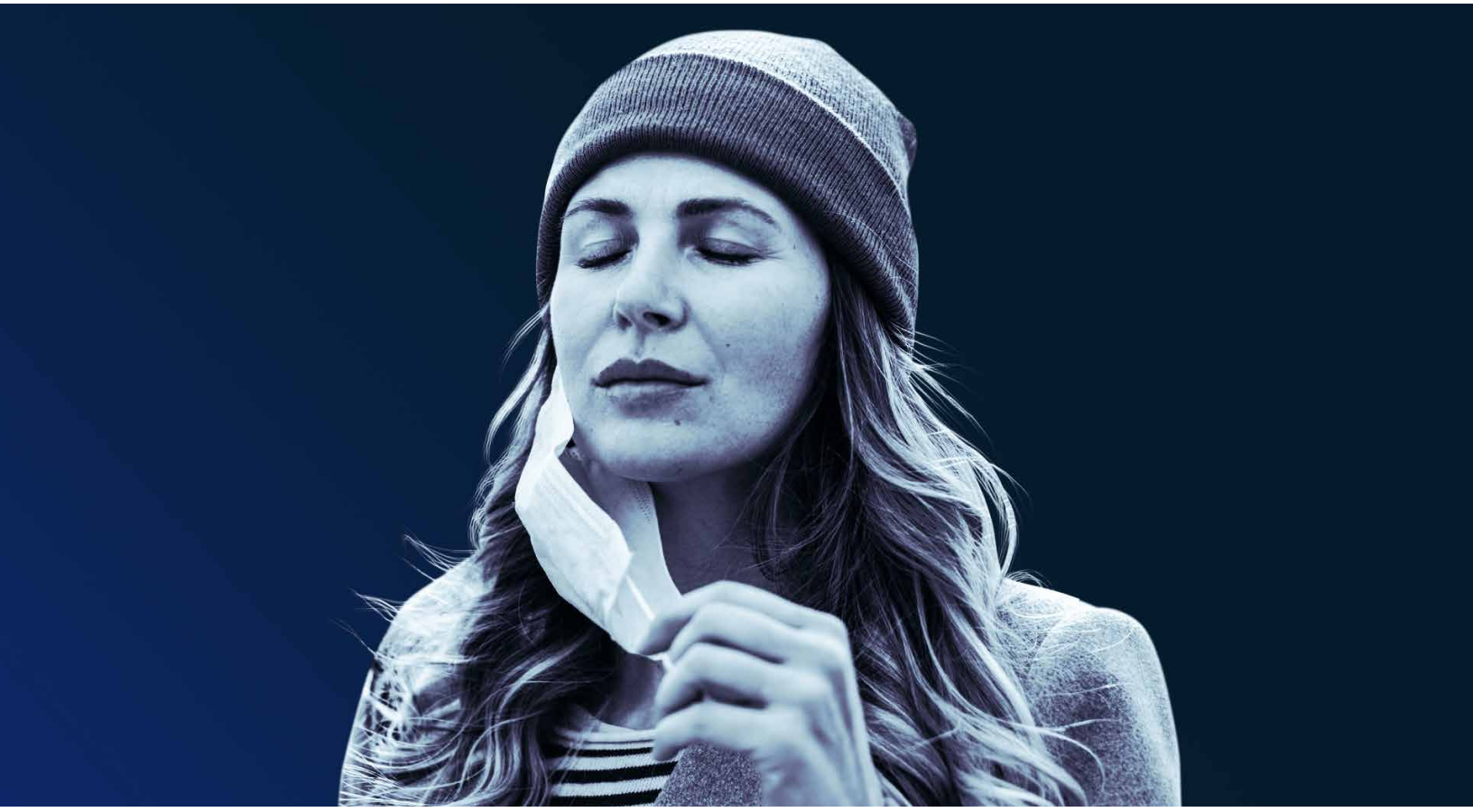
# When will the COVID-19 pandemic end? An update

This article updates our earlier perspectives on when the coronavirus pandemic will end. Transition toward normalcy in the United States remains most likely in the second quarter of 2021 and herd immunity in the third and fourth quarters, but the emergence of new strains and a slow start to vaccine rollout raise real risks to both timelines. We also add a perspective for the United Kingdom.

*by Sarun Charumilind, Matt Craven, Jessica Lamb, Adam Sabow, and Matt Wilson*





January 2021

**The past five weeks** have brought an array of conflicting news on the COVID-19 pandemic, affecting our estimates about when the coronavirus pandemic will end. Margaret Keenan, a British nonagenarian, made history on December 8 by becoming the first person to receive the Pfizer-BioNTech vaccine for SARS-CoV-2 outside a clinical trial.[1] Since then, several other vaccines have been authorized for use around the world. Sufficient doses are likely to be available to vaccinate high-risk populations in the United States in the first half of 2021. In parallel, however, more-infectious strains of the virus have been detected in South Africa, the United Kingdom, and elsewhere and have spread to an increasing number of countries.[2] And the initial rollout of vaccines has been slower than hoped in many places.[3]

While the United States could still achieve herd immunity in the third or fourth quarter of 2021 (in line with the peak probability in our previous estimates), the emergence of more-infectious variants of SARS-CoV-2 increases the risk that this milestone will not be achieved until later. More-infectious viruses require that a higher percentage of people be simultaneously immune to reach herd immunity.[4] While a more infectious variant likely means more people are acquiring natural immunity through infection (despite ongoing efforts to minimize new cases), the net impact of more-infectious strains is likely to be that a higher portion of the population needs to be vaccinated, which may take more time.

We still believe that the United States can transition toward normalcy during the second quarter of 2021, but the same risks also threaten this timeline. A transition toward normalcy would be driven by a combination of seasonality aiding a decline in cases and early vaccine doses helping reduce mortality by protecting those at greatest risk of serious illness. As COVID-19's impact on health wanes, we are likely to see greater normalization of social and economic life. Data on the availability of vaccine doses in the United States increase confidence that this is possible, but the slow start to the vaccine rollout reinforces that success is by no means guaranteed.

This article describes "most likely" timelines for when the coronavirus pandemic will end. It is now harder to imagine the United States or United Kingdom transitioning to normalcy before second quarter 2021 or reaching herd immunity before third quarter 2021. But a number of other factors could delay the timelines beyond those described, including unexpected safety issues emerging with early vaccines, significant manufacturing or supply-chain delays, continued slow adoption, further mutation, or a shorter-than-anticipated duration of vaccine-conferred immunity. Herd immunity will also require vaccines to be effective in reducing transmission of SARS-CoV-2, not just in protecting vaccinated individuals from getting sick. This is likely, but has not yet been proven at scale.[5]

## Herd immunity

### More-infectious strains raise the bar

Herd immunity to a pathogen is achieved when a sufficient portion of a population is simultaneously immune to prevent sustained transmission. The threshold to achieve it is governed by a number of factors, including the transmissibility of the disease.[6] More-infectious strains of SARS-CoV-2 therefore raise the bar on herd immunity. The virus has been mutating since it was identified a year ago. The concerning development in recent weeks has been the confirmation of new strains in South Africa, the United Kingdom, and elsewhere that combine multiple mutations and have different profiles. While data are still emerging, initial estimates suggest that the transmissibility rate of the UK strain is 40 to 80 percent higher than that of the original SARS-CoV-2 strain, and that transmission rates could be higher among children too.[7,8] There is no evidence of higher case fatality with either new strain, but there are fears

[1] "Covid-19 vaccine: First person receives Pfizer jab in UK," BBC, December 8, 2020, bbc.com/news.
[2] Miriam Berger, "U.K. variant continues to spread around the world as coronavirus pandemic enters 2021," *Washington Post*, January 2, 2021, washingtonpost.com.
[3] Michelle R. Smith, "Governors scramble to speed vaccine effort after slow start," *Associated Press*, January 6, 2021, apnews.com.
[4] Ken Eames, Paul Fine, and David L. Heymann, "'Herd immunity': A rough guide," *Clinical Infectious Diseases*, 2011, Volume 52, Number 7, pp. 911–6, academic.oup.com.
[5] Sabin Russell, "Vaccines stop COVID-19 symptoms, but do they stop transmission?," *Fred Hutch News Service*, December 16, 2020, fredhutch.org.
[6] Eames, Fine, and Heymann, "'Herd immunity': A rough guide," pp. 911–6.
[7] Erik Volz et al., *Transmission of SARS-CoV-2 Lineage B.1.1.7 in England: Insights from linking epidemiological and genetic data*, Imperial College London, December 2020, imperial.ac.uk.
[8] Nicholas Davies et al., *Estimated transmissibility and severity of novel SARS-CoV-2 Variant of Concern 202012/01 in England*, Centre for Mathematical Modelling of Infectious Diseases, December 2020, cmmid.github.io.

that new strains may affect how antibodies bind to the virus and may reduce the efficacy of vaccines or antibody treatments developed over the past few months. More data are likely to emerge on this in the weeks ahead.

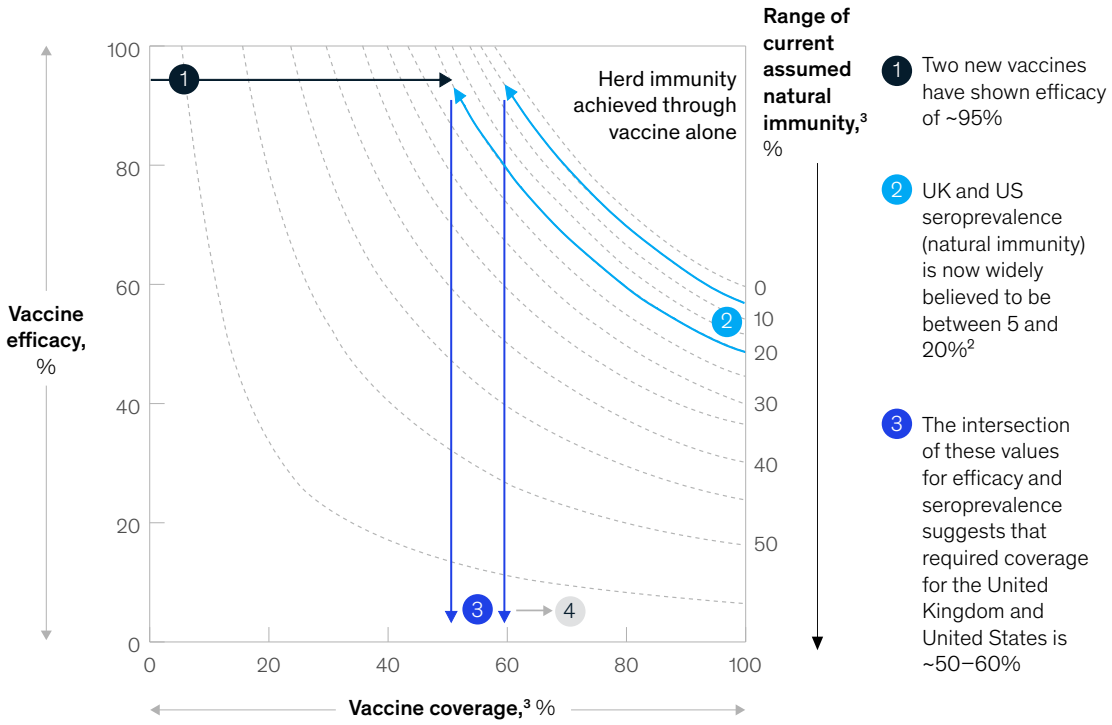
If these strains become dominant, they may cause a material delay in reaching herd immunity. While many people are acquiring natural immunity through infection, variants with enhanced transmissibility, if they predominate among all strains, could increase the proportion of people who need to be simultaneously immune to achieve herd immunity by ten to 20 percentage points, and increase vaccine coverage levels needed to 65 to 80 percent of the population (or 78 to 95 percent of those over 12 years old).[9] More detail is shown in Exhibit 1 below.

[9] Based on a reproduction number (R0) of 2.4 for the original strain and assuming that the herd immunity threshold can be approximated using the formula 1- (1/R0). For more, see Eames, Fine, and Heymann, "'Herd immunity': A rough guide," pp. 911–6. Estimates of increased vaccine coverage needed are based on R0 = 3.36-4.32, which is 40–80% greater than R0 of 2.4.

Exhibit 1

## Prior vaccine coverage estimates assumed that without intervention, each COVID-19 infection could lead to ~2.4 more infections.

**UK and US COVID-19-immunity scenario[1]**




4 While the model assumes the vaccines are distributed to adults and children, the new vaccines may not be available to children in the near term. If only those over 12 years old are vaccinated, coverage may need to be 20% higher (i.e., 60–70% vaccine coverage)

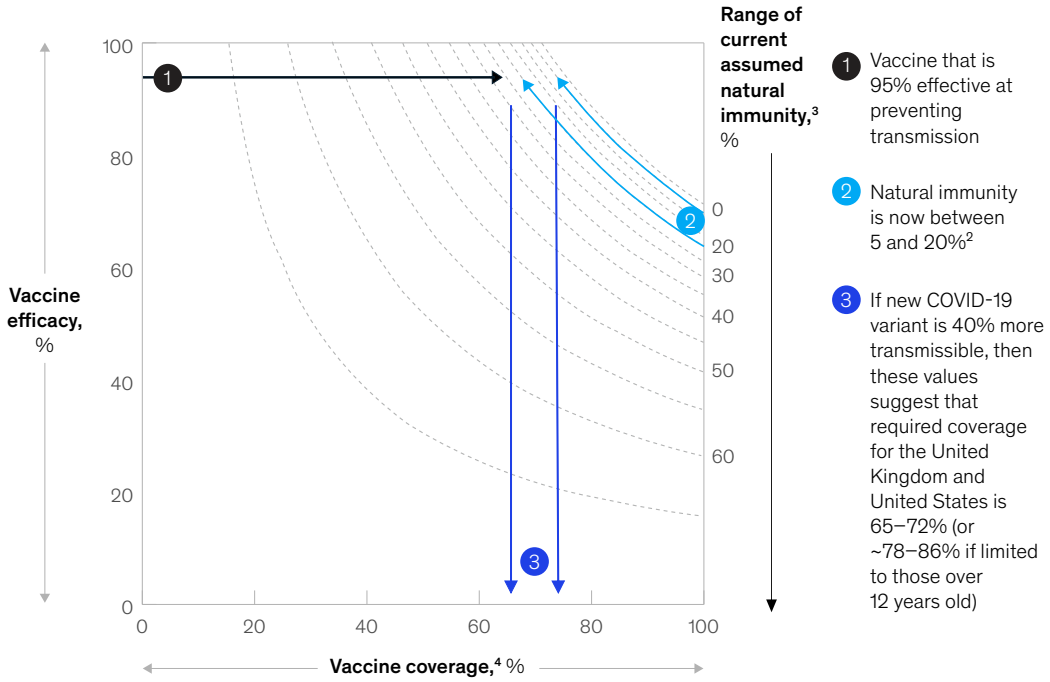
[1] COVID-19 herd immunity achieved once total immune population reaches 58%, using a basic reproductive number (R0) of 2.4; herd-immunity threshold calculated as 1—(1/R0). The model assumes that each member of a population mixes randomly with all other population members. In reality, people mix mostly with others whose patterns of interaction are similar to their own. Subpopulations with fewer interactions have lower thresholds for herd immunity than do those with more interactions.
[2] Summary statistics, SeroTracker, January 11, 2020, serotracker.com. Our model assumes that test seropositivity correlates with natural immunity. Research is ongoing to validate this. If US seroprevalence continues to rise, then minimum vaccine coverage levels required will decrease.
[3] Assumes vaccine is equally available to entire population, regardless of whether they have had COVID-19.
Source: Moderna; Pfizer; SeroTracker; US Census Bureau

Exhibit 1 *(continued)*

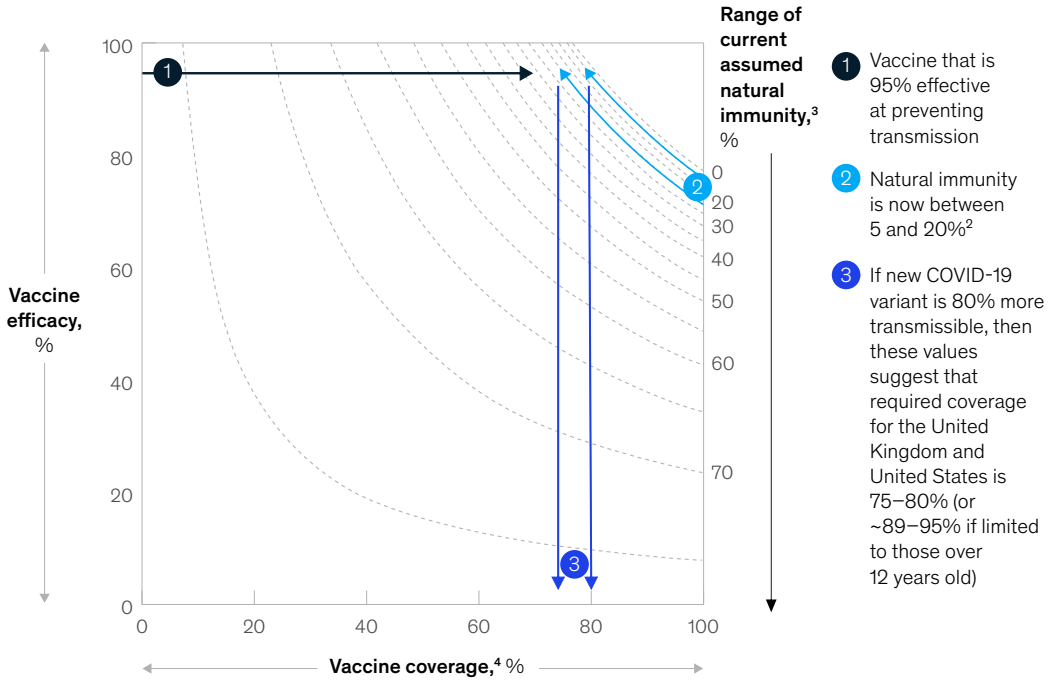
# If more 40–80% transmissible variants predominate and more stringent nonpharmaceutical interventions are used to manage them, then required vaccine coverage would rise.

**Alternative UK and US COVID-19-immunity scenarios[1]**

COVID-19 strain that is 40% more transmissible[2]




COVID-19 strain that is 80% more transmissible[2]




[1] If transmissibility increases by 40% or 80%, then COVID-19 herd immunity is achieved once total immune population reaches 70% or 77%, using basic reproductive numbers (R0) of 3.4 or 4.3, respectively; herd-immunity threshold calculated as 1—(1/R0). The model assumes that each member of a population mixes randomly with all other population members. In reality, people mix mostly with others whose patterns of interaction are similar to their own. Subpopulations with fewer interactions have lower thresholds for herd immunity than do those with more interactions.
[2] Imperial College London and The Centre for the Mathematical Modelling of Infectious Diseases at the London School of Hygiene & Tropical Medicine.
[3] Summary statistics, SeroTracker, January 11, 2020, serotracker.com. Our model assumes that test seropositivity correlates with natural immunity. Research is ongoing to validate this. If US seroprevalence continues to rise, then minimum vaccine coverage levels required will decrease.
[4] Assumes vaccine is equally available to entire population, regardless of whether they have had COVID-19.
Source: Moderna; Pfizer; SeroTracker; US Census Bureau

Vaccinating more people is a nonlinear challenge. Consumer surveys suggest that a portion of the population is cautious about vaccination.[10] Increasing coverage from 70 to 80 percent is therefore harder than increasing from 60 to 70 percent. Because more-transmissible variants raise herd-immunity thresholds, there will also be less tolerance for low vaccine effectiveness. For example, with a variant that is 40 to 80 percent more transmissible, vaccine efficacy of 90 percent would require 83 to 100 percent of those over 12 to be vaccinated; efficacy of anything less than 75 percent would make herd immunity likely unachievable through vaccination of only those over 12.

While the variant of concern appears to be most widespread in the United Kingdom, it has been detected in over 30 countries, many of which (including the United States) have limited capacity for genetic sequencing. As a result, we may be significantly underestimating its spread.[11,12] The strain is likely to continue spreading in the coming months, propelled by its reproductive advantage over the original. This appears to have occurred in southern England over the past few months. If new strains predominate, they could lead to a longer timeline to herd immunity.

### Vaccine rollout: A slow start, but there is still time to improve

The speed of COVID-19 vaccine development has been an unqualified success. The approval, in at least one country, of vaccines made by Pfizer and BioNTech, Moderna, Oxford and AstraZeneca, Sinopharm, Serum Institute, Bharat Biotech, Gamaleya, and others within a year of viral sequencing smashed all records for development timelines. But rollout is off to a slow start. While countries such as Israel have shown what is possible, the United States has fallen behind its targets. [13,14] It is still early days, and there is time to accelerate, but there is little margin for error if the United States is to achieve herd immunity in third quarter 2021. In addition, not all regions are adhering closely to manufacturer dosing protocols—for example, delaying second doses or giving a first dose from one manufacturer followed by a second from another—and the impact of that is unclear. These approaches could reduce mortality in the short term by broadening access, but they could also delay herd immunity if, for example, a delayed second dose reduces efficacy. It's also possible that once most people in the highest-risk groups have received vaccinations, the pace of vaccination will slow if lower-risk groups do not embrace the opportunity.

We believe that herd immunity in the United States is still most likely in third or fourth quarter 2021, but that the chance of delay until first quarter 2022 or beyond has increased (Exhibit 2). There is relatively little chance of achieving herd immunity before then. Even later herd immunity remains possible if other challenges arise, especially vaccine safety concerns or ambivalence to vaccination following a transition toward normalcy. This potential delay represents a call to action for policy makers, both in terms of the pace of the vaccine rollout and how new strains are managed.

### Increasing recognition of medium-term endemicity

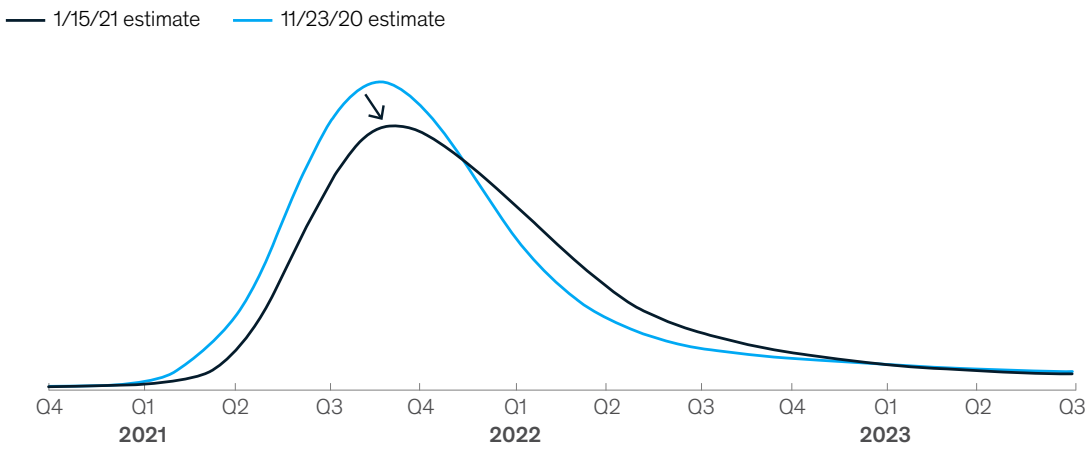
While many parts of the world are expected to reach herd immunity against COVID-19, there is increasing consensus that globally, SARS-CoV-2 is likely to remain endemic in the medium term. David Heymann, the chairman of the World Health Organization's Strategic and Technical Advisory Group for Infectious Hazards, noted in December that endemicity may be the "destiny" of this virus.[15] This might make COVID-19 analogous to measles—a disease that causes intermittent, limited outbreaks in countries with well-developed vaccination programs but significant ongoing disease in parts of the world where access to vaccines is more limited. It is also possible that COVID-19 will be seasonal, with predictable annual peaks in parts of the world where it is endemic.[16]

[10] Tara Azimi, Michael Conway, Tom Latkovic, and Adam Sabow, "COVID-19 vaccines meet 100 million uncertain Americans," December 18, 2020, McKinsey.com.
[11] Miriam Berger, "U.K. variant continues to spread around the world as coronavirus pandemic enters 2021," *Washington Post*, Jan 2, 2021, washingtonpost.com.
[12] Carl Zimmer, "U.S. is blind to contagious new virus variant, scientists warn," *New York Times*, January 6, 2021, nytimes.com.
[13] "Coronavirus: Israel leads vaccine race with 12% given jab," *BBC*, January 3, 2021, bbc.com.
[14] Michelle R. Smith, "Governors scramble to speed vaccine effort after slow start," *Associated Press*, January 6, 2021, apnews.com.
[15] Melissa Davey, "WHO warns Covid-19 pandemic is 'not necessarily the big one,'" *Guardian*, December 29, 2020, theguardian.com.
[16] Apoorva Mandavilli, "The future of the coronavirus? An annoying childhood infection," *New York Times*, January 12, 2021, nytimes.com.

Exhibit 2

## More-transmissible variants and slower initial vaccine rollout increase downside risk to the Q3–Q4 2021 timeline to achieve herd immunity.

**Probability of herd immunity[1] to COVID-19 pandemic for the United Kingdom and United States[2] by quarter** (illustrative)




**Early herd immunity if:**

- Vaccine rollout and adoption are faster than expected
- Natural immunity is significantly higher than realized
- More-transmissible variants lead to higher rates of natural immunity

**Peak probability of herd immunity driven by:**

- US Biologics License Applications (BLA) with full approval by March/April 2021 or earlier
- Approximately 3–9 months for manufacturing, distribution, and sufficient adoption to reach herd immunity

**Later herd immunity if one or more of the following occur:**

- Safety issues delay BLA
- Manufacturing/supply-chain issues slow rollout
- More-infectious variants raise the threshold for achieving herd immunity
- Adoption is slower than anticipated
- Duration of immunity is short
- Vaccine prevents disease progression but does not meaningfully reduce transmission

[1]Herd immunity is achieved when a sufficient portion of a population is simultaneously immune to prevent sustained transmission. At this point, significant, ongoing public-health measures are not needed to prevent future spikes in disease and mortality (this might be achieved while there are still a number of people in particular communities who still have the disease, as is the case with measles).
[2]Timeline to functional end is likely to vary somewhat based on geography.

## Transition toward normalcy

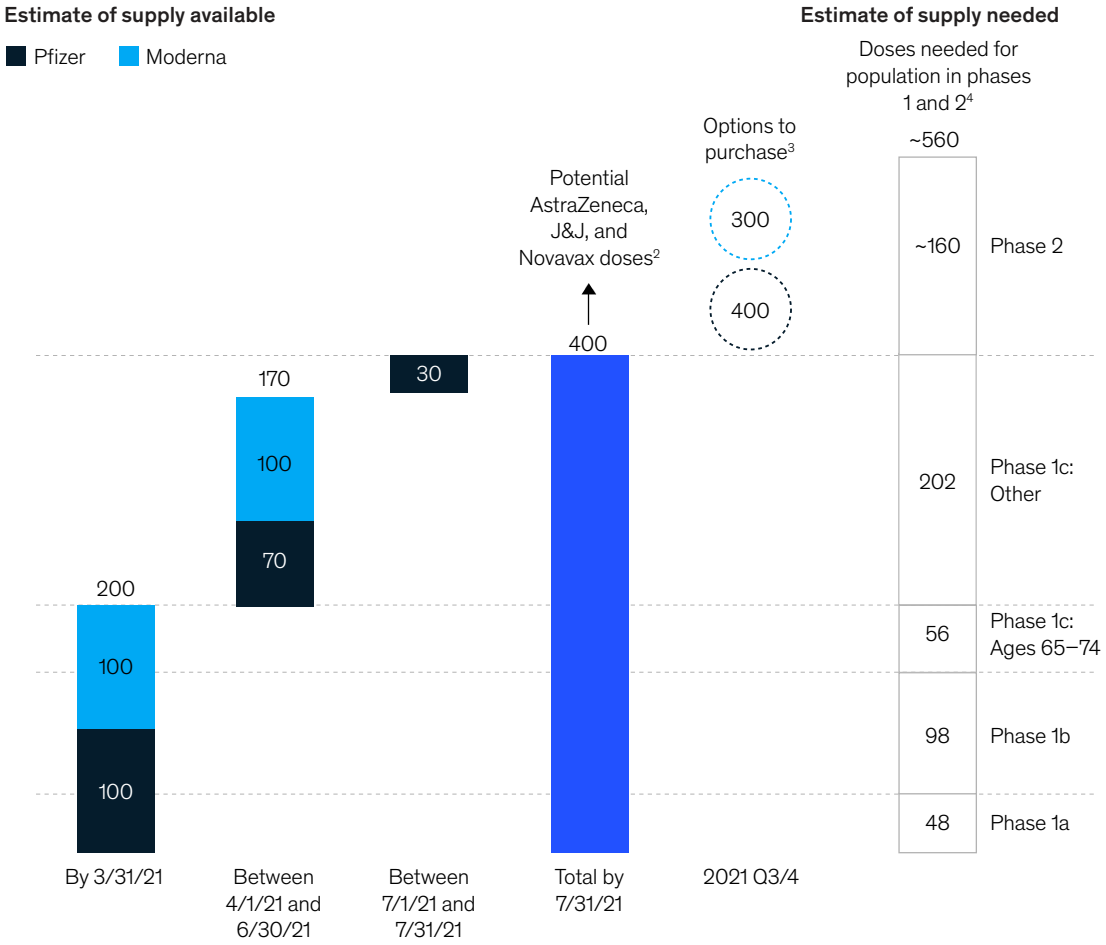
A transition toward normalcy will occur when COVID-19 mortality falls and the disease is de-exceptionalized in society. COVID-19 will not disappear during this transition, but will become a more normal part of the baseline disease burden in society (like flu, for example), rather than a special threat requiring exceptional societal response. During this transition, controlling the spread of SARS-CoV-2 will still require public-health measures (such as continued COVID-19 testing and mask use in many settings), but mortality will fall significantly, allowing greater normalization of business and social activities. This will be driven by a combination of early vaccine rollout (which, being directed first at those at greatest risk, should reduce deaths faster than cases), seasonality, increasing natural immunity, and stronger public-health response.

Increasing clarity on the availability of vaccine doses during the first half of 2021 in the United States improves the odds of an early transition toward normalcy. As Exhibit 3 shows, Pfizer and Moderna are expected to deliver sufficient vaccine doses to vaccinate all high-risk Americans during the first half of the year. This does not account for other vaccines that are likely to become available, including those approved in other markets (for example, Oxford-AstraZeneca) or others that are likely to report clinical trial data in the first quarter of 2021 (including Johnson & Johnson and Novavax). Older people are generally more willing to be vaccinated than the general population. However, slow initial rollout of the vaccines and the spread of more infectious variants increase the risk that significant mortality continues in the second quarter, blunting a transition to normalcy.

Exhibit 3

## In the United States, doses committed by Pfizer and Moderna by July 31 are approximately enough for population in phases 1a–c.

**Delivery deadlines for vaccines with Emergency Use Authorization in the United States,** millions of doses[1] (illustrative)




[1] Two doses needed per person.
[2] Subject to regulatory authorization.
[3] Timing not specified.
[4] According to CDC ACIP interim recommendations (December 22, 2020), will vary as individual states are making their own decisions (CDC phase 1a = healthcare personnel, long-term care facility residents; CDC phase 1b = frontline essential workers, persons aged ≥75 years; CDC phase 1c = persons aged 65–74 years; persons aged 16–64 years with high-risk medical conditions; essential workers not recommended for vaccination in phase 1b); phase 2 estimate based on 2019 census population estimate of persons aged ≥16, less population accounted for in CDC estimates of persons covered in phases 1a-c; CDC and Operation Warp Speed vaccination guidelines may evolve over time.
Source: Bloomberg; DC; HHS; Moderna; Pfizer; Reuters; WSJ

Taking these variables into account, we still believe that a transition toward normalcy is likely during second quarter for the United States, but that downside risks have increased. If early vaccine doses reach a significant percentage of high-risk elderly individuals by the end of quarter one, the combination of protecting these groups and the arrival of spring in the northern hemisphere should improve the situation compared with where the United States is now. Depending on vaccination progress over the summer (whether the United States is on the earlier or later end of the herd immunity window), there may be a smaller fall wave of disease in third to fourth quarter 2021.

While the potential for a transition toward normalcy in just a few months is encouraging, many signs suggest that the next six to eight weeks will be difficult. Case and death numbers are at or near all-time highs in many locations, new variants may accelerate short-term transmission, and vaccine rollout has not yet proceeded far enough to protect much of the population. Strong public-health measures will remain critical to saving lives during this period.

## Timeline for the United Kingdom

We see similar dynamics in the United Kingdom. Three factors lead us to believe that timelines for herd immunity and transition toward normalcy in the United Kingdom will be similar to those in the United States. First, access to vaccines is sufficient to immunize a large percentage of both the US and UK populations during 2021. Second, public willingness to be vaccinated is generally similar between the two countries.[17] Third, the fraction of US and UK residents who already have natural immunity from prior infection is in the same range (with significant variability among regions within countries).[18]

The variant of concern represents a potential source of difference. While it is known to be highly prevalent in the United Kingdom and present in the United States, there is a significant chance that it will predominate throughout the United States over the coming months. All else being equal, countries with a higher proportion of more-infectious variants—assuming they increase public-health measures to handle them—are likely to achieve herd immunity later.

We will add a perspective for other parts of the world, including the rest of Western Europe, in future updates to this article.

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Twelve months ago, most people weren't thinking about COVID-19. Today, much of the world is intensely focused on it, but we can reasonably expect the imminent threat to abate. Much work remains to be done. In the short term, public-health measures can help control the pandemic, but even when herd immunity is achieved, managing the risk of COVID-19 will require monitoring, potential revaccination, and treatment of isolated cases. Every country has its own COVID-19 story, but those stories will eventually reach some kind of ending.

[17] Jeffrey V. Lazarus et al., "A global survey of potential acceptance of a COVID-19 vaccine," *Nature Medicine*, 2020, nature.com.
[18] "SeroTracker," Public Health Agency of Canada, accessed 1/12/21, serotracker.com.

**Sarun Charumilind** is a partner in McKinsey's Philadelphia office, **Matt Craven** is a partner in the Silicon Valley office, **Jessica Lamb** is a partner in the Philadelphia office, **Adam Sabow** is a senior partner in the Chicago office, and **Matt Wilson** is a senior partner in the New York office.

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