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POLICY BRIEF

21-11 Economic Costs and Benefits of Accelerated COVID-19 Vaccinations

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I. INTRODUCTION

Just as COVID-19 produced a global economic shock, the COVID-19 vaccination programs are generally understood to be a prerequisite for a return to normalcy in our social and economic lives. Emergency measures to research, test, produce, and distribute vaccines have been expensive, but increases in GDP resulting from the vaccines are expected to exceed those costs by wide margins. Few studies have quantified the economic costs and benefits of different rates of COVID-19 vaccination, however. This Policy Brief focuses on developing such a quantitative assessment for the United States; the approach may be applied to other countries as well.

Two illustrative scenarios support the conclusion that most plausible options to accelerate vaccinations would have economic benefits that far exceed their costs, in addition to their more important accomplishment of saving lives. This Policy Brief shows that if, for example, the United States had adopted a more aggressive policy in 2020 of unconditional contracts with vaccine producers, the up-front cost would have been higher but thousands of lives would have been saved and economic growth would have been stronger. Instead, the federal government conditioned its contracts on the vaccines' being proven safe and effective. The projections presented here show that even if unconditional contracts led to support for vaccines that failed the phase III trial and ultimately were not used, the cost would have been worth it.

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The few studies that have addressed this issue find that vaccinations lead to very substantial increases in GDP relative to their cost. Juan Castillo and colleagues (2021) calculate that a baseline path of global vaccinations, in which it would take two years to vaccinate 70 percent of the world's population, would boost global GDP by $8.7 trillion compared with an alternative without vaccinations; a faster pace of vaccination that hastens the end of the pandemic by 10 months would lead to an additional $970 billion in world GDP. But this study relies on outdated (mid-2020) estimates of the effect of the pandemic on global GDP. It also does not account for adjustments by households and businesses that have moderated the economic effect of the disease. Cem Çakmakli and colleagues (2021) do not calculate the economic benefits of vaccination per se, but they find that failure to vaccinate the world's developing economies could cost the world between $1.5 trillion and $6.1 trillion; impacts on the United States alone could be as high as $670 billion. Their analysis for the most part relies on a calibrated general equilibrium model, and it is unclear how well it mirrors real-world behavior.

Our study differs from this and other research in a number of ways. First, our estimates of the economic effects of the pandemic are based on an empirical model of the responses of GDP to COVID-19 deaths and lockdown regulations. Second, we focus primarily on the effects of vaccination on the US economy. And, finally, rather than attempting to quantify the economic effects of an all-or-nothing vaccination effort, we consider the effects of faster or slower paths of vaccination, compared with a baseline path projected by public health experts. This narrower focus is more useful because it narrows the spotlight to allocation decisions that can yet be made by policymakers or that could be made in a future pandemic. It should also be more realistic, in that moving from no vaccination program to a rapid program would likely induce substantial changes in economic and personal behavior that would not occur with incremental differences in the pace of vaccination.

As previous studies have found, vaccinations are indisputably cost-efficient, but owing in part to the more marginal changes in the pace of vaccination under consideration here the effects are less dramatic. For example, one scenario assumes that, prior to the launch of phase III vaccine trials last year, the federal government had signed unconditional contracts to purchase vaccines from the producers instead of the conditional contracts it actually used. The unconditional contracts would have exposed the government to the risk of paying for some vaccines that were not effective—but it would have enabled producers to begin large-scale production three to four months earlier than they actually did, with the immediate distribution of 4 million doses of vaccine per day on the granting of Emergency Use Authorization, saving 35,000 lives and boosting 2021 GDP by $64 billion. The estimated incremental cost of this scenario is no more than $20 billion and potentially much less. The fiscal effects alone (higher taxes and less entitlement spending) would exceed the cost of faster vaccinations by at least $12 billion, meaning that there would actually be no net cost to the government of accelerating vaccinations in this manner. Thus, all told, the approach to procurement specified in this scenario not only saves many lives but also raises US GDP and reduces the fiscal deficit.

We also examine a slower-than-baseline scenario, based on the pace of vaccinations that has occurred and is projected for the European Union. This leads to 16,000 more deaths and $36 billion in lower GDP, compared with direct cost savings of only around $1 billion to $2 billion and a net increase in the fiscal deficit of at least $16 billion. We believe other plausible scenarios in which vaccines are accelerated or retarded would have similar cost-benefit results.

Although our methodology is more empirically grounded than other studies, it is still subject to a large range of uncertainty. Nevertheless, we find wide margins of benefits over costs despite conservative assumptions. Accordingly, it is clear that policymakers should be searching much more intensely for ways to accelerate vaccinations both now and in future pandemics. Saving lives is surely the most important reason to do so, but it is comforting to know that there are large net economic benefits.

Our focus is on the United States, but our empirical estimates also apply to other advanced economies. We leave the analysis of developing economies for future work, but we are confident that benefits exceed costs there as well especially if the less expensive vaccines are used.

II. ALTERNATIVE VACCINATION PATHS AND HEALTH OUTCOMES

Our baseline vaccination path is that assumed by the Institute for Health Metrics and Evaluation (IHME) as of April 19, 2021.[1]

- **Baseline:** The pace of daily vaccinations ramps up sharply in April and then returns to near zero by late May. IHME assumes that 175 million American adults get at least one shot and 155 million are "effectively" vaccinated by summer, after which no more vaccines are sought by the US population. This assumption is based on surveys of people's willingness to accept the vaccine (about 69 percent of adult Americans would have received at least one shot, which IHME assumes is sufficient to drive COVID-19 deaths to minimal levels).

We consider two alternatives to the baseline path. The "preproduction" path assumes that, during the summer of 2020, the federal government had committed with the various vaccine producers to make unconditional purchases of their vaccines as soon as they were ready to start phase III trials (which involve testing on large numbers of subjects), but before those trials had proven successful and garnered approval by the Food and Drug Administration (FDA). By the start of the phase III trials, the final composition of the vaccine was settled and companies could have begun mass production. For Moderna and Pfizer, the two companies providing the vast majority of vaccines for Americans, production could have started in August 2020 instead of November 2020.[2]

1 IHME projections are available at www.healthdata.org/covid/updates. Detailed data on vaccination history can be found at https://ourworldindata.org/covid-vaccinations.

2 The US government contracted to purchase 100 million doses of Pfizer's vaccine on July 22, 2020, and 100 million doses of Moderna's vaccine on August 11, 2020, but these contracts were contingent on a successful phase III trial and FDA approval. Moderna and Pfizer began to ramp up large-scale production in November, ahead of FDA approval, based on positive trial results. In our preproduction scenario, Moderna and Pfizer would have begun the ramp-up in August and would have had enough doses on hand by the middle of December to distribute 4 million doses a day indefinitely. See U.S. Government Engages Pfizer to Produce Millions of Doses of COVID-19 Vaccine, HHS Press Office, July 22, 2020; Pfizer Update On Our U.S. COVID-19 Vaccine Candidate Distribution Preparedness, Pfizer press release, November 16, 2020; and Moderna Reports Third Quarter 2020 Financial Results and Provides Business Updates, Moderna press release, October 29, 2020. Johnson & Johnson's vaccine development was somewhat behind those of Moderna and Pfizer, but it too waited for FDA approval before large-scale production. See Johnson & Johnson confident in 1B dose goal for COVID-19 vaccine next year, looking ahead to 2022, Fierce Pharma, November 12, 2020.

This arrangement differs from the baseline (that is, what actually transpired) in that the actual contracts signed by the government in 2020 were conditional on a successful phase III trial and FDA approval. Although the vaccine companies started to secure facilities and line up suppliers immediately after the contracts were signed, they waited until after phase III results became available to start large-scale production. As a consequence, relatively little vaccine had been produced at the time of FDA approval.

In the preproduction scenario, total purchases through the end of 2021 would be for as many as four times the number of doses assumed in the baseline path.[3] The excess purchases would be made in anticipation that some of the vaccines would fail or be markedly less successful in phase III trials. But insofar as every producer would have been paid for a contracted number of doses, whether or not they were successful, the companies would have ramped up production capacity in advance of the trials.[4] Supplies would thus have been available to begin immediate large-scale distribution of vaccines with FDA Emergency Use Authorization.[5] We assume the federal government, coordinating with state and local authorities as well as the companies, would have set up the distribution system in advance of vaccine approvals and production.

To provide a sense of the range of plausible vaccination paths and their consequences, we also consider a slower-than-baseline path that mimics the expected trajectory of vaccinations in the European Union (scaled in proportion to the US adult population), based on the latest IHME projections. The European Union was less aggressive than the United States in securing vaccines during 2020. Figure 1 displays the baseline and two alternative vaccination paths.

- **Preproduction:** This path assumes that 4 million doses are administered each day starting at the beginning of baseline vaccinations (December 16, 2020) and continuing until mid-March 2021. The same share of the population is ultimately covered as in the baseline path, but coverage is achieved more than two months earlier.
- **European:** Vaccinations in this path start two weeks later than baseline and ramp up more slowly, reaching the same plateau as in the baseline by the beginning of July 2021.[6] This path is based on actual EU data through April 19 and IHME projections thereafter. The path is scaled in proportion to the US adult population.

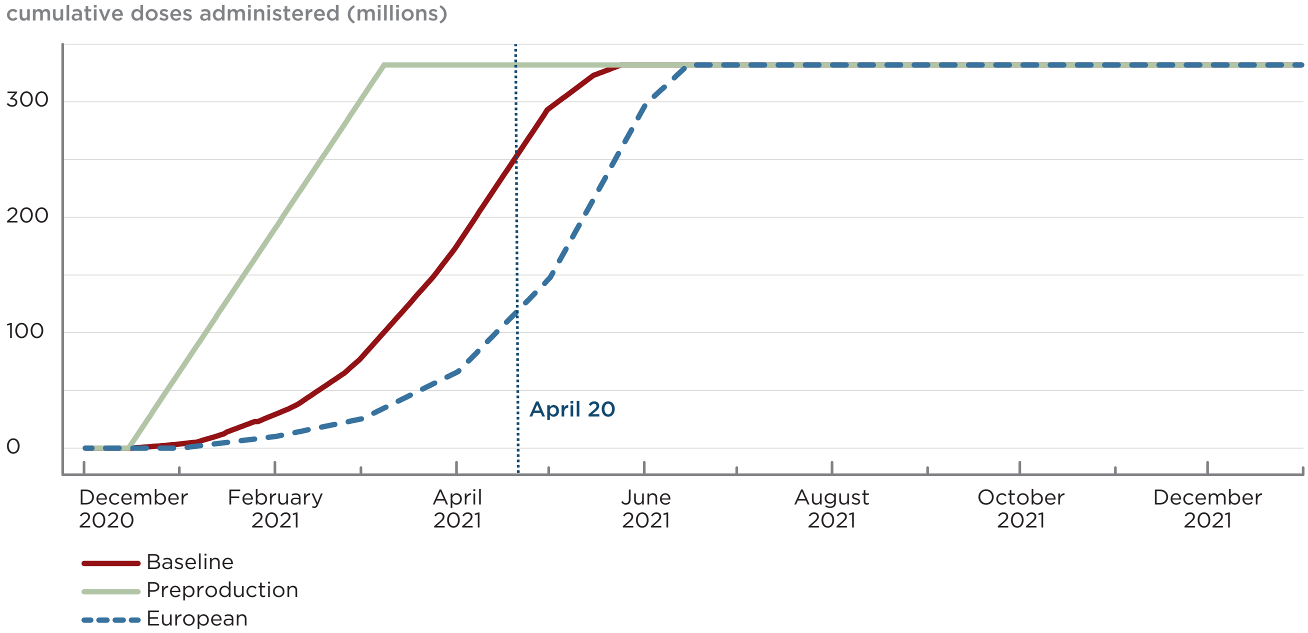
3 The number of doses actually contracted by the federal government is nearly four times as many as assumed in the baseline path. It is not clear how many will be delivered in time to be useful for Americans (or delivered at all because they may not receive FDA approval), but the government is likely to be able to sell or donate them for use abroad. Thus, excess doses in the preproduction path may not have a very high net cost.

4 In the event that a producer's vaccine does not prove effective, the government and the producer could bargain for a reduction in the number of doses produced in exchange for some sharing of the cost savings.

5 Although production would have begun three to four months earlier than otherwise, it is likely that cumulative production by mid-December 2020 would not have equaled actual production as of late March 2021, owing to bottlenecks and congestion effects. To distribute 4 million doses a day starting in mid-December, as assumed in the preproduction scenario, cumulative production would have needed to be accelerated by only two months. See Moderna And Pfizer On Track To Hit Vaccine Production Goals, NPR, March 11, 2021.

6 IHME assumes a slightly higher plateau in Europe based on surveys of vaccine acceptance. We apply the IHME American plateau in this scenario, as our intent is to gauge what would happen in the United States had the government chosen a slower path of vaccinations.

Figure 1
Path of vaccinations under baseline and alternative scenarios, December 2020–December 2021



Note: Projections for the baseline scenario start on April 20, 2021.
Sources: Institute for Health Metrics and Evaluation (IHME); authors' calculations.

The baseline path of deaths is from the IHME's reference scenario and is consistent with the baseline path of vaccination. The IHME projects deaths to decline steadily to 179 per day by August 1, 2021. This path assumes that no people are vaccinated after late May. We assume that the decline in deaths from late May to late July reflects a lag in the buildup of immunity following vaccination plus a lag between infection and death but that these lags are mostly played out by August 1. Thus, we extrapolate deaths at the August 1 rate through the end of the year. The results are not sensitive to different assumptions about deaths in the second half of the year because all the differences in the alternative scenarios occur before August 1.

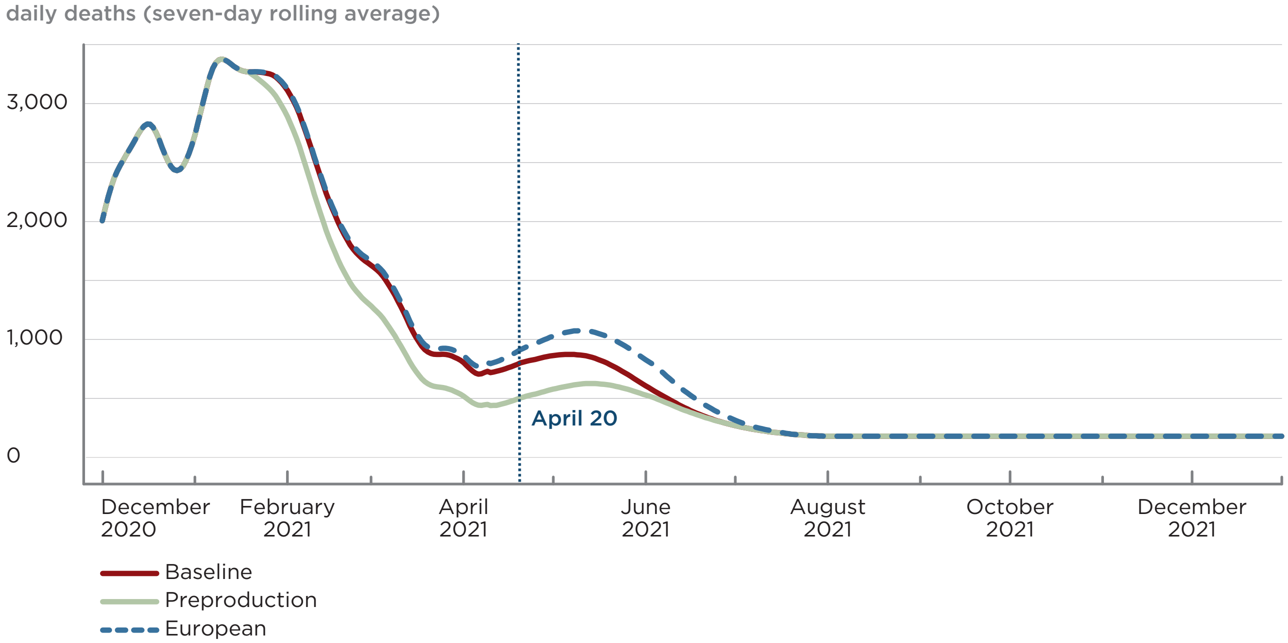
For each of the alternative paths of vaccinations, we adjust daily deaths based on the difference between baseline and alternative vaccination rates. We assume that each vaccine dose reduces the risk of death by 47.5 percent, based on the two-dose efficacy of the Pfizer and Moderna vaccines of 95 percent.[7] We assume a lag of 14 days from each dose to the increased immunity, and a lag of 21 days from infection to death. Thus, vaccines do not reduce daily deaths until 35 days

7 There are two offsetting errors, which are each relatively minor. First, we assume that all of the 155 million "effectively" vaccinated adults in the IHME projection get two doses of Pfizer or Moderna; but a modest fraction of those will actually get the Johnson & Johnson single-dose vaccine that is 72 percent effective, slightly reducing overall effectiveness. On the other hand, the IHME projects that 22 million people will skip the second dose of Pfizer and Moderna vaccines. Because the first dose provides more marginal effectiveness than the second, this would slightly raise the overall effectiveness of a given number of doses.

after injection. After these lags run their course, deaths decline or rise in inverse proportion to the rise or decline in total vaccinations relative to population.

Figure 2 displays the baseline and alternative paths of daily deaths. In total, the faster pace of vaccination under the preproduction path translates into 35,000 saved lives in 2021[8]; the European scenario costs 16,000 lives.

Figure 2
Path of daily deaths under baseline and alternative scenarios, December 2020–December 2021



Note: Projections for the baseline scenario start on April 20, 2021.
Sources: Institute for Health Metrics and Evaluation (IHME); authors' calculations.

III. ECONOMIC BENEFITS OF VACCINATION

The economic benefits of vaccination are measured as the boost to GDP caused by reduced voluntary social distancing and official lockdown requirements as the pandemic is suppressed. We also consider the monetary value of lives saved, and the fiscal boost (higher revenues) from higher GDP.

III.1 Method for Assessing Effects on Real GDP of Different Vaccination Paths

To assess the impact of the vaccinations on real GDP, we use a panel regression model applied to 23 high-income economies that have published quarterly GDP data for most or all of 2020, including the United States (see appendix). The quarter-to-quarter percent change in real GDP is regressed on the arithmetic (not percent) change in the number of deaths per capita in that quarter (which

8 We also implemented the Atkeson (2021) nonlinear SEIR (Susceptible-Exposed-Infective-Recovered) model of epidemics, creating residuals to track the baseline path and then calculating the change in deaths implied by the preproduction path of vaccinations. The preproduction path saved 46,000 lives, modestly above the estimate from our linear approach, suggesting that our benefit calculation is conservative.

is believed to influence the extent of voluntary social distancing), the arithmetic change in a measure of lockdown restrictions (the Oxford Stringency Index, or OSI), and lagged GDP growth.[9,10]

One issue we had to address is the likely endogeneity of deaths and lockdown restrictions. For example, a rise in social distancing not associated with increases in deaths or more stringent lockdowns—as might occur in response to a successful public information campaign—could simultaneously lead to declines in COVID-19 cases, deaths, OSI, and economic activity; this could bias the coefficients on deaths and OSI to be more positive. To address this concern, we use a two-stage procedure: In the first stage, COVID-19 deaths and OSI are regressed on contemporaneous COVID-19 cases; in the second stage, the residuals from these regressions—that is, the variation in deaths and OSI not directly related to contemporaneous cases—are substituted for actual deaths and OSI.

Table 1
Panel regressions for real GDP growth, high-income countries

	2020	2020H1	2020H2
(Intercept)	-0.0046 (0.0051)	-0.0476*** (0.0071)	0.0369*** (0.0061)
Δ Quarterly deaths	-0.2160*** (0.0316)	-0.1271** (0.0497)	-0.0449* (0.0233)
Δ Quarterly Oxford Stringency Index	-0.0003 (0.0002)	0.0006*** (0.0002)	-0.0005 (0.0003)
Lagged dependent variable	-0.1150 (0.0820)	0.2671 (0.2920)	-0.3770*** (0.0656)
R^2	0.5329	0.5000	0.7647
Adjusted R^2	0.5170	0.4642	0.7479
Number of observations	92	46	46
Root mean square error	0.0497	0.0327	0.0274

*p < 0.10; **p < 0.05; ***p < 0.01
Note: See appendix for the list of countries.
Source: Authors' calculations.

Table 1 presents the estimation results. Note that the coefficients in the regression estimated over the entirety of 2020 (column 1) imply implausibly large effects on GDP if applied to 2021. For example, the model predicts that if COVID-19

9 This follows the approach applied by Kamin and Kearns (2021) to industrial production data.
10 See Oxford University's COVID-19 Stringency Index.

deaths fell from their 2020Q4 average of 1,567 per day to zero by the end of 2021, and OSI fell to zero from its 2020Q4 average of 68.5, this would ultimately boost US GDP by 11.1 percent. This outsized effect probably reflects the fact that, in the initial outbreak of the pandemic, the practice of social distancing reacted very strongly to even small COVID-19 death counts and lockdown restrictions were crudely and indiscriminately applied. As households, workers, and businesses adjusted to the new environment, the effect of deaths and lockdowns on economic activity diminished. Accordingly, we use the estimates based on 2020H2, (the third column in table 1) to gauge the effect of the easing pandemic on economic activity. These coefficients suggest that the eradication of deaths and lockdowns from their 2020Q4 level would boost GDP by 4.0 percent, a more plausible increase that leads to a more conservative estimate of the benefits.

As an alternative approach to estimating the economic effects of pandemic variables, we estimated the same econometric model as described above, but using data on GDP, COVID-19 deaths, and OSI from the 50 US states and the District of Columbia instead of high-income countries. The estimation results are presented in table 2.

Table 2
Panel regressions for real GDP growth, US states

	2020	2020H1	2020H2
(Intercept)	-0.0049* (0.0029)	-0.0411*** (0.0033)	0.0411*** (0.0015)
Δ Quarterly deaths	-0.0665*** (0.0109)	-0.0208*** (0.0060)	0.0028 (0.0028)
Δ Quarterly Oxford Stringency Index	-0.0015*** (0.0002)	0.0004** (0.0002)	-0.00001 (0.00009)
Lagged dependent variable	-0.159*** (0.0820)	2.886*** (0.3180)	-0.390*** (0.0166)
R^2	0.5129	0.7293	0.9354
Adjusted R^2	0.5056	0.7210	0.9334
Number of observations	204	102	102
Root mean square error	0.0425	0.0213	0.0088

**p* < 0.10; ***p* < 0.05; ****p* < 0.01
Source: Authors' calculations.

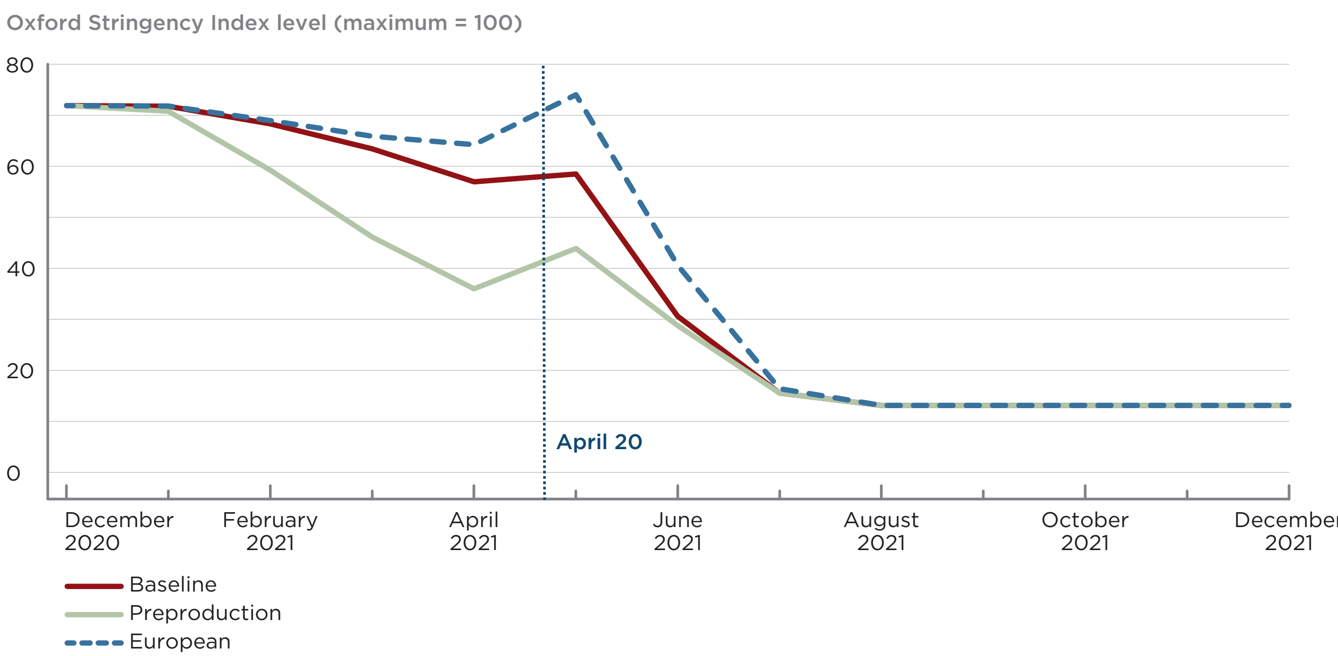
The coefficients for the full 2020 year, while different from those estimated for the cross-country dataset, have similar implications for GDP when taken together: the eradication of COVID-19 deaths and OSI would boost US GDP by 11.6 percent.

However, using the data from only the second half of 2020, the coefficient on deaths is positive and both coefficients are minuscule and insignificantly different from zero. It is possible that the variation in deaths and OSI was not sufficiently great in the second half of 2020 to permit precise identification of pandemic economic effects. It may also be that the considerable economic integration of US states, compared with the economies in our cross-country dataset, meant there was less variation in GDP performance across states that could be used to identify pandemic effects.

As a further check on the economic effect of COVID-19 on the United States, we note that US GDP in 2020Q4 was 4.4 percent below a steady 2 percent growth path from its 2019Q4 level. This figure is very close to the 4.0 percent number cited above, which was the estimated effect of reducing deaths and lockdown restrictions to zero from their 2020Q4 levels, using the coefficients from our multicountry regression for the second half of 2020.

Based on these considerations, we used the model estimated from the multicountry dataset over the second half of 2020 (table 1, column 3) to form our projections. To use the model to project future GDP, we need to enter as inputs not only the projections for COVID-19 deaths discussed above, but associated paths of lockdown restrictions (OSI). The relationship between deaths and OSI has been quite loose and appears to vary over time. But it is likely that if the virus were largely eliminated (100 percent decline in deaths), then lockdown restrictions would be largely eliminated (100 percent decline in OSI). Accordingly, we assume that projected percent declines in deaths will translate on a one-for-one basis to percent declines in OSI, as shown in figure 3.

Figure 3
Path of restrictions (Oxford Stringency Index) under baseline and alternative scenarios, December 2020–December 2021



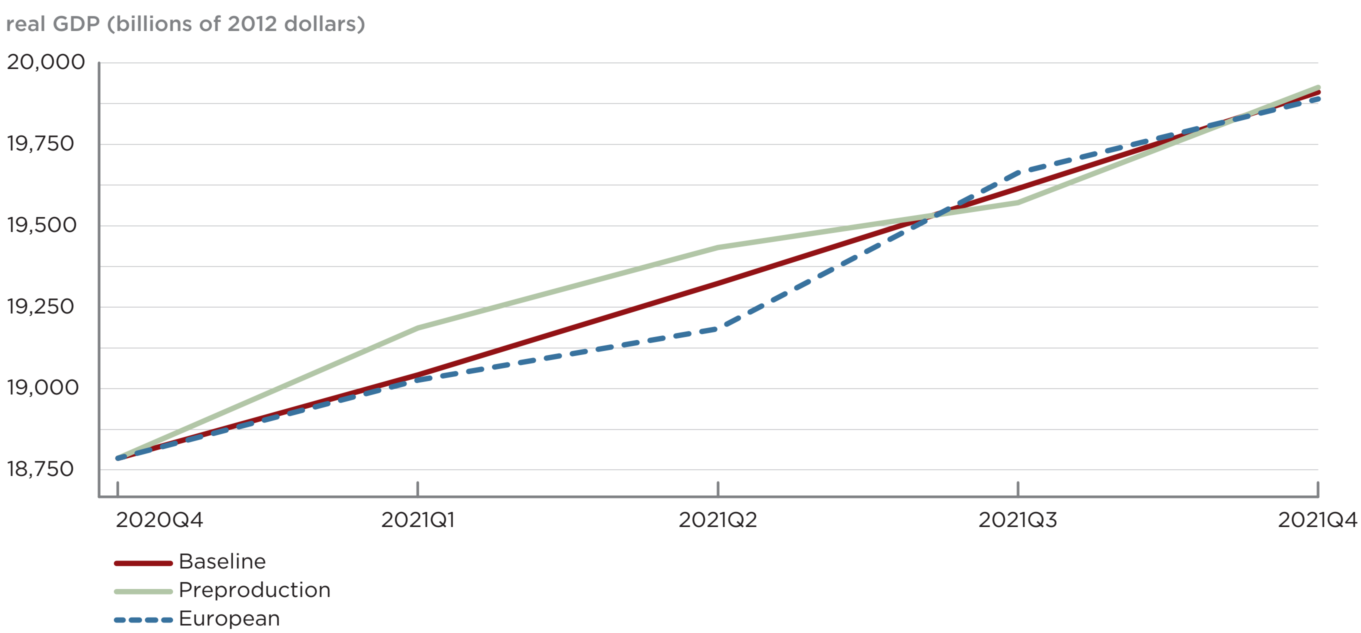
Note: Projections for the baseline scenario start on April 20, 2021.
Sources: Institute for Health Metrics and Evaluation (IHME); Oxford University; authors' calculations.

III.2 Estimated Effects of Alternative Vaccination Paths on GDP

To assess the effects of vaccinations on GDP, we start by specifying a baseline path for GDP, based on the March 2021 *Consensus Forecast* projection. This entails Q4/Q4 growth of 6.0 percent in real GDP. We assume that this path of GDP is associated with our baseline path of vaccinations, deaths, and OSI described above. We then use our model to estimate how deviations in vaccinations and deaths from baseline in our alternative vaccination paths translate into alternative paths for GDP.

Figure 4 compares the baseline path of real GDP (annual rate) to these alternative GDP paths. In the preproduction scenario, the initial more rapid decline in deaths and OSI induced by the faster pace of vaccinations leads to more rapid GDP growth in Q1. However, insofar as deaths and OSI end up in the same place as in the baseline scenario by midyear, these pandemic indicators improve less quickly than in the baseline by the second quarter, after which GDP in the two scenarios converges. The opposite effect occurs with the EU path: Q1 GDP grows more slowly than in the baseline in response to a slower improvement in pandemic indicators, but then catches up to baseline by the third quarter.

Figure 4
Real GDP under alternative vaccination scenarios, 2020Q4–2021Q4



Note: Projections start in 2021Q1.
Sources: Institute for Health Metrics and Evaluation (IHME); Oxford University; authors' calculations.

Table 3 summarizes the projected results for 2021 as a whole; the second column converts GDP in 2012 constant dollars to 2020 current dollars to facilitate comparison with costs incurred in 2020. The faster pace of vaccinations in the preproduction scenario increases 2021 GDP by $64 billion; if US vaccinations followed the EU path, GDP would be $36 billion lower (column 3).

Table 3
Projected economic activity in 2021 under three vaccination paths

Path	2021 real GDP[a]	2021 nominal GDP[b]	GDP deviation from baseline[b]	2021 COVID-19 deaths	Deaths, deviation from baseline	Value of lives saved above baseline[b]	Economic benefits above baseline[b]	Fiscal balance above baseline[b]
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Baseline	19,472	22,121	n.a.	293,392	n.a.	n.a.	n.a.	n.a.
Preproduction	19,529	22,185	+64.30	258,429	-34,963	+174.81	+239.11	+32.15
European	19,441	22,084	-36.15	309,381	+15,989	-79.94	-116.09	-18.08

n.a. = not applicable

a. 2012 USD billions.

b. 2020 USD billions. Nominal GDP is calculated by scaling our estimate of 2021 real GDP by 1.136, the ratio of nominal to real US GDP in 2020.

Source: Authors' calculations.

III.3 Adding in an Estimate of the Cost of Human Lives

Obviously, the primary benefit of faster vaccinations is to save lives. To quantify the unquantifiable, and ensure that we take this critical element into account in addition to the effect on GDP, we assume each life saved is worth $5 million.[11] The fifth and sixth columns of table 3 indicate that the preproduction scenario would save 35,000 lives, valued at $175 billion; the European scenario would cost an additional 16,000 lives, or $80 billion.

Adding up the valuations for GDP and lives saved (column 7), the preproduction scenario entails benefits of $239 billion, while the European scenario implies total costs of $116 billion.

III.4 Impact on Fiscal Balances

Leaving aside central concerns about the value of human life, any expenditures on faster vaccinations will be worthwhile as long as they are exceeded by the economic benefits. That said, to the extent that the higher GDP induced by faster vaccinations leads to higher tax revenues and reduced spending on unemployment benefits and other entitlement programs, this helps the federal government finance those expenditures and limits the rise in public debt. Applying the OECD's fiscal balance semi-elasticity for the United States of 0.50

11 As of 2016, the value of a statistical life at four US government agencies ranged from $9 to $10 million. The government does not apply any premium for youth or discount for age, but this may reflect the political sensitivity of doing so. Arguably, deaths of older (i.e., retired) people ought to be viewed as less costly as they have fewer years left to live. See No One Values Your Life More Than the Federal Government, Bloomberg, October 19, 2017.

(Price, Dang, and Botev 2015), as shown in table 3, column 8, implies an increase in fiscal balance (reduced deficit) of about $32 billion in the preproduction scenario and a loss of $18 billion in the European scenario.

IV. ECONOMIC COSTS OF VACCINATION IN DIFFERENT SCENARIOS

The cost of the Moderna and Pfizer vaccines is roughly $20/dose.[12] The cost of the Johnson & Johnson vaccine is roughly $15/dose, but relatively few doses are expected to be delivered before the plateau of vaccinations in our scenarios.[13] The cost of administering the vaccine is estimated at no more than $20/dose, but this cost should not be affected by accelerating or delaying vaccine administration provided that reasonable advance preparation is made.[14] The total cost of the 332 million doses of vaccines in our scenarios is no more than $13 billion.[15]

Assuming that four times as many doses were prepurchased in our preproduction scenario at the Moderna/Pfizer cost per dose, the total cost would be less than $33 billion and the extra cost would be no more than $20 billion.[16] If only two times as many doses were prepurchased, the extra cost would be less than $7 billion but there would be a somewhat greater risk of not having 4 million doses/day of an effective vaccine as early as we assumed.

It may be objected that, to incentivize so many additional doses from Pfizer and Moderna in the preproduction scenario, a much higher price per dose would have been required. However, in this scenario, the government's commitment to buy so many doses would have been spread across all the relevant producers, in the hopes that at least some of these companies would have produced successful vaccines. In fact, six companies received contracts from the federal government, and if each of their vaccines prove successful, the government would have purchased some 1.2 billion doses.[17] Therefore, in this scenario, Pfizer and Moderna

12 See Biden Administration purchases additional doses of COVID-19 vaccines from Pfizer and Moderna, ASPR Press Office, February 11, 2021. The additional purchases, from 400 million doses by end-June to 600 million doses by end-July, also cost $20/dose. These additional doses would not be needed in our paths, but may be needed if doses are administered to children or vaccine hesitancy diminishes. On May 10, the FDA authorized use of the Pfizer vaccine for 12- to 15-year-olds. See Coronavirus (COVID-19) Update: FDA Authorizes Pfizer-BioNTech COVID-19 Vaccine for Emergency Use in Adolescents in Another Important Action in Fight Against Pandemic, FDA press release, May 10, 2021.

13 See U.S. to pay $1 billion for 100 million doses of Johnson & Johnson's COVID-19 vaccine candidate, Reuters, August 5, 2020. The Johnson & Johnson vaccine is about as effective as the Pfizer and Moderna vaccines after one dose. Johnson & Johnson is conducting a trial that may show its vaccine is also equally effective as those vaccines after two doses.

14 The cost of administering vaccines in pediatric practice was estimated at $11.51/dose in 2009 (Glazner, Beaty, and Berman 2009).

15 However, the United States has now committed to buying many more than 332 million doses of vaccine, which may be useful if more adults can be persuaded to accept them, or if it is proven safe to administer them to young children. In addition, extra doses can be exported or donated to developing nations.

16 As discussed in Bown and Bollyky (2021), the US government also provided around $1 billion in subsidies to companies that make inputs for vaccines. It is not clear how much these subsidies reduce the costs of the several vaccines that are being produced or in development in the United States. Arguably, the preproduction scenario might call for an additional $1 billion or so of advance subsidies to suppliers.

17 See Covid-19 Deals Tracker: 9.6 Billion Doses Under Contract, Bloomberg, March 9, 2021.

do not produce more doses than in the baseline, but rather produce them earlier. It is possible that incentivizing the earlier production may have required a higher price, but that is highly uncertain.

It is less clear how to assess the savings from the European scenario. The European Union was less aggressive than the United States in securing multiple vaccine commitments, bargained harder to obtain lower prices, and focused on the cheapest vaccine (AstraZeneca), which appears to be somewhat less effective than other vaccines (Kirkegaard 2021). For the more effective Pfizer and Moderna vaccines, the European Union reportedly saved $5/dose on Pfizer and $2/dose on Moderna.[18] For equal amounts of each vaccine scaled by the 332 million doses in our scenarios, the savings in the European scenario would be $1.2 billion.

V. CONCLUSION

The most important benefit of speeding up the production and distribution of COVID-19 vaccines is that it saves lives. On top of that, the results presented in this paper show that the economic benefits from faster vaccinations far exceed their costs. Indeed, the economic benefits are so great that higher tax revenues and lower entitlement spending are likely to exceed any government spending needed to accelerate vaccination. There is a tremendous amount of uncertainty in measuring the economic gains, but the magnitude of the gains is so large, and the assumptions used are so conservative, that we can be highly confident that there are net benefits of almost any reasonable action to speed up vaccinations.

We based our results on US data, but our technique can easily be applied to other countries. For other advanced economies, we expect similar results. For emerging-market and developing economies, given the large margin of benefits over costs, accelerated vaccination is also likely to have net economic benefits, especially if one places a greater emphasis on the less costly vaccines.

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APPENDIX

Table A1 shows the list of 23 high-income countries used in the panel regressions.

Table A1
Countries used in panel regressions

Luxembourg	Finland
Switzerland	Germany
Ireland	Belgium
Norway	Canada
Iceland	Israel
United States	United Kingdom
Singapore	New Zealand
Denmark	France
Australia	Japan
Netherlands	Italy
Sweden	South Korea
Austria	

Note: Countries ranked by GDP per capita (2019) in descending order.

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