COVID-19 vaccines:
Saving lives and the global stock markets

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Abstract:
Global stock markets react positively when different phases of human clinical trials on COVID-19 vaccine candidates begin. The average increase in stock market returns on day one of the trials is 15.2 basis points, and this estimate is both economically and statistically significant. The market reactions also show cross-phase and cross-country variations. We use a simple capital budgeting framework to explain the finding that stock markets convey important information about market-wide expectations on vaccine development that evolve along with the pandemic.

Key words: COVID-19; pandemics; stock markets; vaccines

JEL Code: G10, G14, I15
1. Introduction

The outbreak of the coronavirus disease 2019 (COVID-19) exerted dire consequences on global financial markets and the world economy. Figure 1 shows that during the onset of the pandemic, key stock market indices declined by nearly 35% over a short time span between February 11 (when the World Health Organization (WHO) coined the term “COVID-19”) and April 2 (when a million infections were reported worldwide). Empirically, a burgeoning literature shows that COVID-19 has negatively affected liquidity (O’Hara and Zhou, 2020), the aggregate equity market (Gormsen and Koijen, 2020; Smales, 2021), individual stocks (Ding et al., 2020; Ramelli and Wagner, 2020), sovereign credit risk (Augustin et al., 2020), firm policies, investment, and financing decisions (Acharya and Steffen, 2020; Fahlenbrach et al., 2020; Halling et al., 2020), and trade, economy activity, and productivity (Baldwin and Tomiura, 2020; Barro et al., 2020; Bloom et al., 2020). In response, many governments around the world have enforced a range of monetary and fiscal policies, together with health restrictions, strict lockdowns, and social distancing measures, to contain the pandemic and stimulate the economy (see, e.g., Baker et al., 2020; Cochrane, 2020; Ding et al., 2020).

< Insert Figure 1 here>

This study contributes to the literature that examines the global response to COVID-19. However, unlike other studies, we explore a novel dimension that has largely been overlooked: vaccine development and its impact on stock markets. A safe and effective vaccine would undoubtedly save lives, and this study shows another benefit that medical research can provide during the development of COVID-19 vaccines: a positive impact on global stock markets.
In particular, we exploit a dataset provided by the WHO and identify the announcement dates of three key phases in human clinical trials of COVID-19 vaccine candidates developed worldwide. Using panel regressions, we estimate the average daily stock market returns during the clinical trials after controlling for other factors that could affect stock markets during the pandemic. We find that stock markets react positively, with an average increase of 15.2 basis points (bps) in global stock returns on day one of the trials. The result is statistically significant and economically meaningful: the 15.2 bps increase translates to a USD 87 billion increase in total market capitalization for 49 countries upon the start of the trials.

Further analysis shows that the stock markets react stronger when clinical trials progress to later phases. Additionally, within the same phase, the reaction is heterogeneous and conditional on the vaccine origins—that is, whether they are developed by pharmaceutical companies domiciled in the U.S., China, or other countries. Finally, we perform a series of robustness checks, including controlling for time zone differences across global stock markets and accounting for vaccines that have concurrent phase 1 and 2 trials, and our key findings continue to hold.

We put forward a theoretical explanation for our findings that traces back to a simple model of capital budgeting. In this model, when vaccine development advances to a later stage, investors would update their beliefs regarding the success rate of the vaccine candidate. Thus, the stock market reacts proportionally to what the vaccine project is expected to provide (i.e., saving lives and saving the economy) given the updated success rate. Our empirical evidence provides support to this hypothesis, suggesting that global stock markets convey important information about market-wide expectations on vaccine development that evolve along with the pandemic.
This study makes the following contributions. First, while existing literature on the impact of medical research typically focuses on certain pharmaceutical stocks or related industries (Huberman and Regev, 2002; Shortridge, 2004), we document and explain the reaction of global stock markets in response to the COVID-19 vaccine development. The vaccine aims to slow the spread of the COVID-19 pandemic, minimize infection, and reboot the world’s economy. Therefore, any potential breakthrough documented during the developmental phase of the vaccine is expected to positively influence the global stock markets, and we provide evidence confirming this prediction.

Although our model suggests that promising news about the vaccine during its developmental phase would positively influence the stock market, skeptics may question this relation because of heterogeneity in different economies. In particular, various governments implemented different monetary and fiscal policies to stimulate their respective economies at different times, and thus, their effectiveness may vary across different stages of the pandemic. Depending on the success of the vaccine in controlling the pandemic, some governments could exit their stimulus policies earlier than expected. A recent study by Acharya et al. (2020) predicts that an early ending to the pandemic would diminish the value of how a vaccine “cures” the economy in terms of labor supply and consumption. If that were the case, vaccine development may exert a negative (rather than a positive) impact on the stock market. Our study addresses this uncertain relation between vaccine development and stock market returns by analyzing the stock markets of countries with heterogeneous economies.

Finally, we investigate stock market returns during all of the three phases involved in human clinical trials. This approach contrasts with prior studies that typically analyze the last phase or final approval of drug/vaccine development (Overgaard et al.,

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2000; Rothenstein et al., 2011). As we will discuss shortly, vaccine development is a costly, highly uncertain, and laborious procedure. In particular, a vaccine candidate must undergo a rigorous pre-clinical evaluation, three phases of human clinical trials, and other administrative-related stages before obtaining final approval/licensure from the relevant governing bodies. As such, we posit that satisfactory results shown in the developmental phase of the vaccine would update and restore investors’ beliefs about the vaccine’s success in resolving the pandemic. An increase in the success rate of the vaccine candidate would affect investors’ beliefs toward the vaccine developer and, in the context of pandemics, the aggregate stock market. This results in an increase in stock market returns, and we provide supporting evidence for this conjecture.

2. Vaccine development and hypotheses

Vaccine development is a lengthy and uncertain process that generally takes around 10–15 years to complete before it enters into large-scale production for public vaccination (Scheppler et al., 2021). During this laborious process, human clinical trials are arguably the key in determining the success (or failure) of the vaccine. An industry report, prepared jointly by several key pharmaceutical bodies, shows that only one-sixth of all the vaccine candidates that have had human clinical trials during the period 2006–2015 obtained final approval for mass production.¹ Given its complexity and importance, we begin this section by describing the three phases involved in typical human clinical trials. We then develop three separate hypotheses to guide our empirical tests.

¹ “Clinical development success rates 2006–2015,” prepared by Biotechnology Innovation Organization, Biomedtracker, and Amplion. Document was accessed from https://www.https://www.bio.org/sites/default/files/legacy/bioorg/docs/Clinical%20Development%20Success%20Rates%202006-2015%20-%20BIO,%20Biomedtracker,%20Amplion%202016.pdf.
2.1 Phase 1, 2, and 3 of the vaccine trials

Phase 1 focuses on the safety of the vaccine, where different dosages are administered to a handful of healthy volunteers. The objective is to ascertain the minimum dose required to create an optimal immune response without causing the test subjects to experience “serious adverse effects.” Phase 2 assesses the safety and efficacy of the vaccine using a larger group of volunteers with different demographics such as age and health condition. In phase 3, a clinical trial on a much larger scale ensues with thousands of volunteers participating. This final phase has the longest duration because it occurs in “natural disease conditions”—that is, the vaccine is administered to a large group of people who are exposed to natural conditions of the targeted disease. Rare adverse effects that could have avoided detection in the first two phases are usually identified in phase 3. For a vaccine intended to protect the global population from a pandemic, two or more phase 3 clinical trials are usually conducted, each in different locations in the same country or in different countries.

In the case of the COVID-19 pandemic, vaccine developers have to consider two important factors: timeliness and variety. With regard to timeliness, the disease’s contagious nature and global urgency mean that the development of a vaccine must be expedited. This results in some developers combining and conducting phase 1 and 2 trials concurrently.\(^2\) Regarding variety, different types of vaccines are tested across the globe. Without delving into scientific details, it suffices to note that four main

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\(^2\) At a given point in time, a vaccine may be reported with “phase 1/2” status. In this case, we attribute the start of such a combined phase to be the start of phase 1 and phase 2, respectively. In Section 5, we provide a robustness check on the impact of these “phase 1/2” observations. In addition, several vaccine candidates are identified as having more than one trial in a certain phase, with each conducted on different groups of people, in different areas, and starting from different dates. In this situation, we consider the earliest date of these trials as the start of the corresponding clinical phase.
types of vaccines—whole virus, protein subunit, nucleic acid, and viral vector—had been tested in human clinical trials by August 7, 2020.³

2.2 Hypotheses development

As noted earlier, human clinical trials involve three phases. The start of each phase marks a milestone in vaccine development because it (i) indicates the successful completion of the previous phase and (ii) updates people’s belief that the vaccine would have a higher likelihood of progressing to the next stage (and eventually obtain approval for large-scale production).

We now discuss a theoretical framework commonly used in capital budgeting to formalize the proposition that the beginning of each clinical trial phase has a positive impact on global stock markets. Denote the initial cost involved in pre-clinical trials as $c_0$ and the respective costs associated with phase 1, 2, and 3 during human clinical trials as $c_1, c_2,$ and $c_3$. Each phase has a success rate of $q_{j=1,2,3} \in [0,1]$. Once all three phases are successfully completed, the vaccine enters mass production and generates revenue ($R$) (i.e., “cash flow of sales” in capital budgeting). In the context of COVID-19, however, $R$ refers to the health and economic benefits for the nation that undertakes the vaccine project and, to a certain extent, political stability between the country in which the vaccine developer is domiciled (hereafter, vaccine developer) and other countries (hereafter, non-vaccine developer).⁴ Therefore, ignoring the time

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³ In the “whole virus” type, the vaccine works by using the weakened “live attenuated” or inactivated form of virus to trigger an immune response. In the “protein subunit” type, the vaccine uses the harmless part of the pathogen to trigger an immune response. In the “nucleic acid” type, the vaccine uses genetic materials such as RNA or DNA to “instruct” human cells to produce certain antigens. In the “viral vector” type, the same treatment philosophy used in the nucleic acid type applies, except that a harmless virus such as an adenovirus is used instead of genetic material to produce the antigen. For further scientific explanations, we refer interested readers to Gavi: The Vaccine Alliance, “There are four types of COVID-19 vaccines: here’s how they work,” https://www.gavi.org/vaccineswork/there-are-four-types-covid-19-vaccines-heres-how-they-work

⁴ This is particularly true for the development of COVID-19 vaccines. First, unlike other vaccines, the government takes a significant role in stopping coronavirus from spreading throughout the world and
value of money without loss of generalization, the capital budgeting model evaluates the net benefit of vaccine development as

$$Rq_1q_2q_3 - (c_0 + c_1) - c_2q_1 - c_3q_1q_2,$$

where the unconditional success rate of the vaccine at time 0 (i.e., on the first day of phase 1) is $q_1q_2q_3$. When a vaccine enters the next phase, the net benefit increases because the probability of generating future $R$ increases. That is, if phase 1 is successful and the clinical trial enters phase 2, the success rate increases from $q_1q_2q_3$ to $q_2q_3$, and the net benefit of the project becomes $Rq_2q_3 - (c_0 + c_1) - c_2 - c_3q_2$. In this case, the expected value of the project increases by $[Rq_2q_3 - c_2 - c_3q_2](1 - q_1)$.

Based on the above derivations, along with the efficient market hypothesis of Fama (1970), we predict that the stock market immediately reflects the fundamental changes in the net benefit of the project when human clinical trials in different phases begin:

$H1$: The stock market return is positive on the first day of each clinical trial phase.

If phase 2 is successful and the clinical trials advance to phase 3, the success rate would increase from $q_2q_3$ to $q_3$, and the net benefit also increases by $[Rq_3 - c_3](1 - q_2)$. When $R$ is large relative to the cost (so that the cost becomes

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5 We emphasize the actual start of different phases of clinical trials rather than the announcement of the start. This is because a vaccine may register for the next phase trial long before it actually starts. The registered trial may be postponed or even cancelled if the current trial doesn’t go as expected (or cannot continue for other reasons). Therefore, we focus on stock market reactions on the actual start of clinical trial phases as they update individuals’ beliefs about a vaccine’s final success.

makes a significant contribution toward the development of the vaccine. For example, the U.S. government has spent $9 billion on the development of COVID-19 vaccines. Second, the immunization is considered as global public goods, and thus the general belief is that all countries throughout the world will benefit from the immunization project of COVID-19 vaccines. This is evidenced by the joint effort to help poorer countries. For example, the G20 countries pledged to pay for a fair distribution of $4.5 billion by the end of 2020 for poorer countries.
negligible), the net benefit on the first day of each clinical trial phase would dramatically increase from 0 to \( R_q q_2 q_3 \) in phase 1, from \( R_q q_2 q_3 \) to \( R_q q_3 \) in phase 2, and from \( R_q q_3 \) to \( R_q \) in phase 3. Thus, the percentage of change in the net benefit of the vaccine project, \( (1/q_1 - 1) \) for phase 2 and \( (1/q_2 - 1) \) for phase 3, would be reflected in the stock market returns on the first day of the corresponding phases.\(^6\) Wong et al. (2019) find that the success rate in vaccine development when moving from phase 1 to phase 2 is considerably greater than when moving from phase 2 to phase 3. Therefore, it is not unrealistic to assume that \( q_1 > q_2 \), which translates to \( (1/q_1 - 1) < (1/q_2 - 1) \). These arguments motivate the second hypothesis:

**H2:** The incremental stock market return on the first day of phase 3 is greater than that of phase 2.

Arguably, vaccines differ from each other in terms of medical fundamentals and success rates, and stock markets are likely to react heterogeneously across vaccine candidates. For example, U.S.-developed vaccines are likely to promote higher confidence (and efficacy perception) among the public globally than non-U.S.-developed vaccines because of the country’s strength in medical research and its dominating position in the global pharmaceutical industry.\(^7\) Conversely, several counterarguments suggest that China is likely to have a higher success rate

\(^6\) For simplicity, we assume revenue is zero if the vaccine does not enter the first phase of human trials. Therefore, the percentage of change in the net benefit is not definable for phase 1.

\(^7\) Anecdotal evidence that supports this argument includes the following: (1) U.S. pharmaceutical companies (such as Pfizer) generally dominate the global vaccine market in terms of market capitalization; (2) the number of U.S. vaccines patented in 1921–2011 is fivefold higher than the number patented by China (5,230 patents by the U.S. versus 1,133 patents by China); and (3) the recent 2018 vaccine scandal in China, which is viewed as the closest competitor to the U.S. in COVID-19 vaccine development, has created a confidence crisis among the public about the safety and quality of vaccines locally developed in China (“Vaccine scandal and confidence crisis in China,” *The Lancet*, vol. 392 (10145), August 4, 2018, DOI: https://doi.org/10.1016/S0140-6736(18)31695-7).
than other countries in the race for developing safe and efficient COVID-19 vaccines.⁸ These arguments lead us to posit that the global stock market reactions are conditional on the vaccine origins:

**H3: Stock markets react differently to vaccines developed in the U.S., China, and other countries on the first day of a certain clinical trial phase.**

### 3. Data and empirical model

We collect data from several sources. First, we retrieve information about vaccine candidates from an official document prepared by the WHO, “Draft landscape and tracker of COVID-19 candidate vaccines.”⁹ From the document, we gather key information such as pharmaceutical companies and research institutions developing the vaccines and countries in which the developers are domiciled.¹⁰ The document also provides links to registration platforms such as ClinicalTrial.gov; we use these platforms to identify the start of each phase in human clinical trials for the vaccine candidates.

The sample period we use to test the human clinical trial phases covers the period from January 2, 2020, through August 7, 2020. This sample period contains 26 vaccine candidates that are developed independently or jointly by institutions from 11 countries (see Table 1). China has the most vaccine candidates under human trials (9

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⁸ In the post-2018 vaccine scandal period, a number of legislative rules and measures have been imposed to regulate vaccine development in China. In the campaign of COVID-19 vaccines, the Chinese government has lent full support to the development, regardless of profitability at the firm level. In fact, three vaccines solely developed in China that have entered phase 3 are either developed by state-owned companies or are developed in cooperation with a research institute with a military background. Another noteworthy factor is that China has more experience in coronavirus vaccine development because of its previous experience with the SARS virus.

⁹ This document is regularly updated and publicly available on the WHO website: World Health Organization, “Draft landscape and tracker of COVID-19 candidate vaccines,” (https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines).

¹⁰ Some vaccines are jointly developed by companies domiciled in different countries. In this case, we consider all the countries as vaccine developers.
candidates), followed by the U.S. (7 candidates). The remaining vaccine developers are from Australia, Canada, Germany, India, Singapore, Japan, South Korea, Russia, and the U.K.

<Insert Table 1 here>

For global stock market data, we rely on the Morgan Stanley Capital International (MSCI) database. In particular, we focus on the MSCI All Country World Index (ACWI) to proxy for the global equity market. The MSCI ACWI consists of 23 developed economies and 26 emerging economies in August 2020; together, these economies make up over 90% of the world’s gross domestic product. For individual countries, we use the corresponding MSCI Investible Market Index (IMI) to measure the country’s stock market return.

First, to test the first two hypotheses, we define several dummy variables and estimate the following regression specification as our main test:

\[ AR_{it} = \phi_t + \phi D_t + \gamma X + \eta_i + \epsilon_{it}, \]

where the matrix \( X \) includes five control variables to capture other forces that may be driving the abnormal returns, following recent studies (see, e.g., Ding et al., 2020): the daily growth rate of COVID-19 confirmed cases (\( \text{Pct\_cases} \)); the daily growth rate of COVID-19 related deaths cases (\( \text{Pct\_deaths} \)), VIX, the American Association of Individual Investors Sentiment Survey bull-bear spread (\( \text{BBsprd} \)), and lagged one

\[ AR_{it} = \phi_{0t} + \phi_{1t} D_{it} + \phi_{2t} D_{it} + \phi_{3t} D_{it} + \gamma X + \eta_i + \epsilon_{it}, \]

The 23 developed economies (as classified by the MSCI) are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong SAR, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the U.K., and the U.S. The 26 emerging economies are Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Greece, Hungary, India, Indonesia, Korea, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Qatar, Russia, Saudi Arabia, South Africa, Taiwan Region, Thailand, Turkey, and the United Arab Emirates.
abnormal returns ($AR_{i,t-1}$). The accompanying appendix provides a discussion of the control variables. Additionally, we include country fixed effects ($\eta_i$) in the regression.

Our key explanatory variables of interest are $D_{1,t}$, $D_{2,t}$, and $D_{3,t}$. For $D_{1,t}$, we dichotomize the first day of phase 1 as one (unconditional on the type of vaccine or country), and zero for other days. A positive (negative) loading on $D_{1,t}$ would suggest that the stock markets react positively (negatively) on the first day of phase 1. The $D_{2,t}$ and $D_{3,t}$ dummy variables are defined analogously for phase 2 and phase 3, respectively. To test our first hypothesis, in equation (1a), we consider replacing $D_{j=\{1,2,3\},t}$ with a single dichotomous variable $D_t$, which takes the value of 1 on the first day of any of the phases of the clinical trials, and 0 otherwise.

To test our third hypothesis, we replace the dummies $D_{j=\{1,2,3\},t}$ with the ones that are associated with a certain group: U.S.-, China-, or Others-developed vaccines. In this way, we can test the reactions of the global stock market in response to vaccines that are developed by different countries.

The dependent variable is daily abnormal return ($AR_{i,t}$) on the IMI of country $i$ on day $t$ and is calculated as

$$AR_{i,t} = R_{i,t} - \left( \hat{\alpha}_i + \hat{\beta}_i \times R_{m,t} \right),$$

where both $\alpha$ and $\beta$ are estimated from the market model $R_j = \alpha_i + \beta_i \times R_{m,t} + \xi_{i,t}$ over the daily estimation window from January to December 2019, and $R_{m,t}$ is the daily return on the MSCI ACWI IMI.
4. Empirical findings

4.1 Testing Hypotheses H1 and H2

We presage the analysis by estimating the daily abnormal returns of all 49 countries on equation (1a), where the dummy variables $D_{j=[1,2,3],t}$ are replaced with a single dichotomous variable $D_t$ that takes the value of 1 on the first day of any phase, and 0 otherwise. Hypothesis H1 surmises a positive stock market return on the first day when the clinical trial begins, leading to a prediction that $\phi$ (the coefficient associated with $D_t$) is positive.

< Insert Table 2 here>

Column (1) of Table 2 provides supportive evidence for H1. The $\phi$ coefficient estimate is 0.1521 ($t$-statistic = 3.03), suggesting that the average abnormal stock market return increases significantly by 15.2 bps when various phases of clinical trials begin. In terms of economic significance, the market capitalization that all 49 MSCI IMIs represent in December 2019 is USD 57 trillion. Our regression finding implies that the total market cap of all 49 countries increases, on average, by USD 87 billion ($= 57,000 \times 0.001521$) upon the start of different phases of clinical trials. The outcomes for the control variables generally accord with our expectations. For example, the coefficient estimate on Pct_cases is negative (-0.5941) and statistically significant, which supports the notion of a negative relation between COVID-19 confirmed cases (i.e., public’s fear level) and stock market returns. The loading on Pct_deaths, however, is not statistically significant.

Column (2) in Table 2 reports the results for the phase-dependent panel regression equation (1) with $D_{j=[1,2,3],t}$ set to 1 on the first day of phase $j$, and 0 otherwise. Providing further support to H1, Column (2) shows that the average abnormal stock
market return on 49 countries increases by 30.0 bps on the first day of phase 2 ($t$-statistic = 3.79), and this estimate increases to 51.7 bps ($t$-statistic = 5.95) on the first day of phase 3. The difference between $\phi_3$ and $\phi_2$ is 21.7 bps (the $p$-value of the difference is less than 10%), as reported in the “$\phi_3$ minus $\phi_2$” row in Table 2. This suggests that on average, stock market returns rise by 21.7 bps more on the first day of phase 3 relative to day one of phase 2, thus confirming the prediction of Hypothesis H2.

Columns (3) and (4) of Table 2 report the findings when we partition the dependent variables into 11 vaccine developers and 38 non-vaccine developers. Note that the key qualitative finding continues to hold: the day-one mean stock market return in phase 2 and 3 increases by 37.4–43.1 bps (statistically significant at the 1% confidence level) for the vaccine developer group and by 27.6–53.4 bps (also statistically significant at the 1% confidence level) for the non-vaccine developer group.

4.2 Testing Hypothesis H3

As noted earlier, China and the U.S. play leading roles in the race to develop COVID-19 vaccines. Hypothesis H3 predicts that stock markets react differently to vaccines developed in China, the U.S., and other countries on the first day of each clinical trial phase. To test this hypothesis, we modify regression equation (1) by replacing $D_{j=[1,2,3],t}$ with $US_{j=[1,2,3],t}$, which is equal to 1 on the first day of phase $j$ for vaccines developed in the U.S., and 0 otherwise. Similarly, we replace $D_{j=[1,2,3],t}$ with $China_{j=[1,2,3],t}$, these are the analogous 0/1 dummy variables for vaccines developed in China. Finally, we re-estimate the regression by dichotomizing the $Others_{j=[1,2,3],t}$

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12 Although hypotheses H1 and H2 have directional predictions, we adopt a conservative approach and use the two-sided $t$-test. Using the one-sided $t$-test would have yielded a stronger significant result.
dummy variables as 1 on the first day of phase $j$ for clinical trials of vaccines developed in countries other than the U.S. or China, and 0 otherwise. For each of the tests, we estimate the modified regression on the abnormal stock market returns for all 49 countries.

< Insert Table 3 here>

Table 3 reports the results. The main takeaway is that with the exception of U.S.-developed vaccines, the abnormal returns of stock markets on the first day of phase 2 and 3 of vaccines developed in China and other countries are significantly higher than those on other days. In particular, Column (1) reports that the average abnormal stock market return on the first day increases by 65.8 bps ($t$-statistic = 4.72) when U.S.-developed vaccines enter phase 3. For the China-developed vaccines, Column (2) shows that the global stock market average return increases by 36.4 bps ($t$-statistic = 4.03) on the first day of phase 2 and by 58.9 bps ($t$-statistic = 6.43) on the first day of phase 3. In the case of vaccines developed in other countries, the stock market average return increases by 39.7 bps ($t$-statistic = 4.20) on day one in phase 2 and by 73.9 bps ($t$-statistic = 4.58) on day one in phase 3. Furthermore, consistent with Hypothesis H2, the last row of Table 3 shows that the average stock market return is significantly more positive on the first day of phase 3 relative to that of phase 2 for the vaccines developed in the U.S., China, and other countries.

5. Further analyses

5.1 Concurrent phase 1 and phase 2

Given the urgency of addressing the COVID-19 pandemic, several vaccine developers concurrently commenced phase 1 and 2 to accelerate the vaccine development process (see Section 2.1). Of the 26 vaccines under consideration, 13
have phase 1 and 2 starting on the same day. Therefore, one might question whether our empirical estimates for phase 1 and phase 2 dummies reported in Section 4 intertwine with each other; that is, a positive stock market reaction could be attributed to either phase 1 or phase 2 development of COVID-19 vaccines, or both. We check the robustness of our results toward this issue by omitting the $D_{1,t}$ variable from the panel regression equation (1) and repeat the tests on Hypotheses H1–H3.

< Insert Table 4 here>

Table 4 reports the regression estimates. For brevity, we only tabulate the estimates of interest: the loadings on $D_{2,t}$ and $D_{3,t}$. In Panel A, we contrast the results of abnormal stock market returns on different groups of countries (49 countries, 11 vaccine developers, and 38 non-vaccine developers), and in Panel B, we investigate the heterogeneity in abnormal stock market returns on all 49 countries conditional on the origin of the vaccines (i.e., whether they are developed in the U.S., China, or other countries).

Similar to what we have observed in Table 2, Panel A of Table 4 shows that the estimates on the $D_{2,t}$ and $D_{3,t}$ dummy variables are positive and statistically significant, with $\phi_3$ being generally significantly greater than $\phi_2$. These findings reaffirm Hypothesis H1 that stock markets react positively on the first day of phase 2 and 3, and Hypothesis H2 that the stock market reaction on the first day of clinical trials is stronger in phase 3 than in phase 2.

When it comes to the question about heterogeneous stock market reactions to vaccines developed in different countries, Panel B of Table 4 reports a set of results similar to those tabulated in Table 3: irrespective of the vaccine origins, stock markets react positively and significantly on day one of phase 2 and 3. Comparing the result
here to what we have obtained in Table 3, it seems that because phase 1 and 2
dummies are largely intertwined, the effect captured by the coefficient associated with
$US_{2,t}$ is dominated by that of $US_{1,t}$. After we drop the phase 1 dummy (shown in Panel
B, Table 4), the loading on $US_{2,t}$ becomes positive and the corresponding $t$-statistic
increases.

5.2 Developed versus emerging markets for non-vaccine developers

We conjecture that vaccine development provides substantial economic and
financial benefits to the country in which the vaccine developer is domiciled. We have
confirmed this hypothesis, with Tables 2 and 3 showing abnormally high stock market
returns on the first day when clinical trials begin. Column (3) of Table 3 further shows
that the day-one abnormally high stock market return finding extends to 38
non-vaccine developers. When the vaccine is expected to benefit the country, the
stock market returns would be positive at the start of human trials. Here, we posit that
of the 38 non-vaccine developers, developed economies are more capable of
purchasing COVID-19 vaccines relative to emerging economies, and this capability
translates to a more positive reaction in the stock markets of developed economies to
vaccine development relative to emerging economies. The counterargument is that
emerging economies of non-vaccine developers (hereafter, non-vaccine emerging
economies) tend to have a weak national health care system and a less resilient
economy; therefore, they rely more heavily on COVID-19 vaccines relative to
developed economies of non-vaccine developers that do not have vaccines under
human trials (hereafter, non-vaccine developed economies), and this triggers a greater
reaction in the stock market of the non-vaccine emerging economies. Therefore, it is
an empirical question whether the economic and financial benefits reported earlier for
non-vaccine developers are homogeneous across non-vaccine developed economies and non-vaccine emerging economies.

< Insert Table 5 here>

We test the panel regression equation (1), first on the group of 16 non-vaccine developed economies and then on the group of 22 non-vaccine emerging economies. Table 5 reports the key coefficient estimates. The main finding is that stock markets in non-vaccine emerging economies typically react stronger than non-vaccine developed economies when phase 2 and 3 clinical trials begin. This finding is consistent with the notion that among non-vaccine developers, emerging economies rely more heavily on the vaccines developed by other countries to get themselves out of the COVID-19 pandemic than developed economies.

5.3 Different time zones

It is worth reiterating that we have identified the first day of each clinical trial phase using information provided by the WHO (see Section 3). Still, the concern is that the first-day indicator is ambiguous because of time zone differences across global stock markets. To alleviate this concern, we repeat the regression analyses by re-dichotomizing the dummy variables in equation (1) so that \( D_{j=1,2,3,t} \) is equal to one over a three-day \([-1, +1]\) event window surrounding the first day of phase \( j \), and zero otherwise. Table 6 reports the regression results, which are qualitatively similar to those reported in Table 2.

< Insert Table 6 here>

6. Conclusions

A plethora of recent papers have shown the negative impact of the COVID-19 pandemic. This study contributes to this active debate by exploring these effects from
a different perspective: do global stock markets react when human clinical trials for
COVID-19 vaccine candidates begin? We show that they do, and that they react
positively.

In particular, we retrieve a dataset from the WHO and identify three key phases in
human clinical trials for various vaccine candidates developed around the globe. We
show that the average abnormal return for stock market indices increases by 15.2 bps
on day one of clinical trials after controlling for factors such as COVID-19 confirmed
cases and COVID-19-related death cases. The result is significant both economically
and statistically. When we condition the analysis on different phases, the result
demonstrates that stock market reactions on the first day are stronger as the clinical
trials progress to later phases. This result is evidenced from a sizable stock market
return increase of 51.7 bps in phase 3 versus 30.0 bps in phase 2. Furthermore, we
show a heterogeneous reaction of the stock market toward vaccines developed by
pharmaceutical companies domiciled in the U.S., China, and other countries.

Our results hold with a set of robustness checks, including controlling for time
zone differences across global stock markets and taking into account the clinical trials
that have concurrent phase 1 and 2. The positive relation between vaccine
development and global stock markets also continues to hold irrespective of whether
the stock market is from a developed economy or an emerging economy. Overall, our
findings suggest that global stock markets convey important information about the
market-wide expectations relating to the development of COVID-19 vaccines.
Appendix

Control variables in regression equation (1)

- Daily growth rate of COVID-19 confirmed cases ($Pct_{cases}$): We use $Pct_{cases}$ to proxy for country $i$’s exposure to COVID-19. Following Ding et al. (2020), we collect the number of confirmed cases in all 49 countries from the WHO’s COVID-19 Dashboard (https://covid19.who.int/) and estimate $Pct_{cases}$ as

$$Pct_{cases,i,t} = \ln(1 + \text{confirmed cases}_{i,t}) - \ln(1 + \text{confirmed cases}_{i,t-1}).$$

- Daily growth rate of COVID-19-related death cases ($Pct_{deaths}$): $Pct_{deaths}$ is our second proxy for country $i$’s exposure to COVID-19. As before, we source the number of COVID-19-related deaths from the WHO’s COVID-19 Dashboard and estimate $Pct_{deaths}$ as

$$Pct_{deaths,i,t} = \ln(1 + \text{deaths}_{i,t}) - \ln(1 + \text{deaths}_{i,t-1}).$$

- Volatility index ($VIX$): We use the CBOE VIX to proxy for investor sentiment across the global market. VIX is widely known as a forward-looking “fear gauge” (Whaley, 1993).

- Bull-bear spread ($BBsprd$): The second proxy that we use to measure investor sentiment is the American Association of Individual Investors Sentiment Survey bull-bear spread, estimated by subtracting the percentage of pessimistic investors who believe that the market would go bearish from the percentage of optimistic investors who believe the market would go bullish.

- One-period lag of abnormal returns ($AR_{i,t-1}$): We use the one-period lag to control for persistency in stock market returns.
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### Table 1: List of Vaccines

This table lists all 26 vaccine candidates that were under human clinical trials as of August 7, 2020. The last three columns report the start dates (expressed in month/day) of clinical trial phase 1, 2, and 3. Blank cells mean the phase had not begun by the end of the sample period used in this study (i.e., August 7, 2020).

| Vaccine developer/manufacturer | Country | Vaccine type   | Phase 1 | Phase 2 | Phase 3 |
|--------------------------------|---------|----------------|---------|---------|---------|
| Wuhan Institute of Biological Products/Sinopharm | China | Whole Virus | 4/11 | 4/11 | 7/16 |
| Beijing Institute of Biological Products/Sinopharm | China | Whole Virus | 4/28 | 4/28 | 7/16 |
| Sinovac | China | Whole Virus | 4/16 | 4/16 | 7/21 |
| Moderna/NIAID | U.S. | Nucleic Acid | 3/16 | 5/29 | 7/27 |
| Pfizer/BioNTech/Fosun Pharma | U.S., Germany, China | Nucleic Acid | 4/29 | 7/27 | 8/5 |
| CanSino Biological Inc./Institute of Biotechnology, the Academy of Military Medical Sciences | China | Viral Vector | 3/16 | 4/12 | |
| University of Oxford/AstraZeneca | U.K. | Viral Vector | 4/23 | 4/23 | |
| Institute of Medical Biology, Chinese Academy of Medical Sciences | China | Whole Virus | 5/15 | 5/15 | |
| Novavax | U.S. | Protein Subunit | 5/25 | 5/25 | |
| Gamaleya Research Institute | Russia | Viral Vector | 6/17 | 6/17 | |
| Genexine Consortium | South Korea | Nucleic Acid | 6/17 | 6/17 | |
| Osaka University/ AnGes/ Takara Bio | Japan | Nucleic Acid | 6/29 | 6/29 | |
| Anhui Zhifei Longcom Biopharmaceutical / Institute of Microbiology, Chinese Academy of Sciences | China | Protein Subunit | 6/22 | 7/12 | |
| Bharat Biotech | India | Whole Virus | 7/13 | 7/13 | |
| Inovio Pharmaceuticals/ International Vaccine Institute | U.S. | Nucleic Acid | 4/3 | 7/15 | |
| Janssen Pharmaceutical Companies | U.S. | Viral Vector | 7/15 | 7/15 | |
| Federal Budgetary Research Institution State Research Center of Virology and Biotechnology "Vector" | Russia | Protein Subunit | 7/27 | 7/27 | |
| Arcturus/Duke-NUS | U.S., Singapore | Nucleic Acid | 8/4 | 8/4 | |
| Cadila Healthcare Limited | India | Nucleic Acid | 7/15 | 8/6 | |
| Imperial College London | U.K. | Nucleic Acid | 6/15 | | |
| Curevac | Germany | Nucleic Acid | 6/18 | | |
| Clover Biopharmaceuticals Inc./GSK/Dynavax | China, U.K., U.S. | Protein Subunit | 6/19 | | |
| People's Liberation Army (PLA) Academy of Military Sciences/Walvax Biotech | China | Nucleic Acid | 6/25 | | |
| Vaxine Pty Ltd/Medytox | Australia, South Korea | Protein Subunit | 6/30 | | |
| Medicago Inc. | Canada | Protein Subunit | 7/10 | | |

13 The vaccine is quite commonly referred to as the “Pfizer-BioNTech” vaccine. We follow the WHO document to define who vaccine developers are. In fact, Fosun Pharma, a health care group in China, has been cooperating with the U.S. company Pfizer and Germany’s BioNTech since the early stages of vaccine development. However, most R&D for the vaccine is done in the U.S. and Germany. Untabulated analysis shows that the results are qualitatively the same if we do not treat this vaccine as a China-developed one.
Table 2: Stock Market Reactions on the First Day of Clinical Trials

The table reports the results of stock market reactions on the first day of vaccine clinical trials with the parenthesized \( t \)-statistics computed using standard errors clustered at the country level. Column (1) reports the empirical estimates of equation (1a) with a parsimonious \( D_i \) dummy variable. Column (2) reports the results for the panel regression equation (1) with \( D_{i,t} \) set to 1 on the first day of clinical trial phase \( j \), and 0 otherwise. We run the panel regression on all 49 countries for analyses reported in Columns (1) and (2). In Columns (3) and (4), we partition the countries into 11 vaccine developers and 38 non-vaccine developers. The last row reports the coefficient differences between \( D_{3,t} \) and \( D_{2,t} \). *, **, *** denote significance levels at 10%, 5%, and 1%, respectively.

|              | All 49 countries | All 49 countries | 11 vaccine developers | 38 non-vaccine developers |
|--------------|------------------|------------------|-----------------------|--------------------------|
|              | (1)              | (2)              | (3)                   | (4)                      |
| \( D_i \)    | 0.1521***        |                  |                       |                          |
|              | (3.03)           |                  |                       |                          |
| \( D_{1,t} \)| -0.0637          |                  | -0.1590               | -0.0380                  |
|              | (-0.72)          |                  | (-0.73)               | (-0.39)                  |
| \( D_{2,t} \)| 0.3004***        | 0.3741*          | 0.2761****            |                          |
|              | (3.79)           | (1.82)           | (3.18)                |                          |
| \( D_{3,t} \)| 0.5172***        | 0.4308**         | 0.5344***             |                          |
|              | (5.95)           | (2.55)           | (5.03)                |                          |
| \( VIX_i \)  | 0.0067           | 0.0070           | 0.0117                | 0.0057                   |
|              | (1.53)           | (1.59)           | (1.18)                | (1.15)                   |
| \( BBsprd_i \)| 0.4130***        | 0.4392***        | 0.2347                | 0.4255***                |
|              | (4.81)           | (4.97)           | (1.11)                | (3.95)                   |
| \( Pct\_cases_{i,t} \)| -0.5941***     | -0.5870***       | -0.1776               | -0.7406***               |
|              | (-4.00)          | (-4.02)          | (-0.67)               | (-4.07)                  |
| \( Pct\_deaths_{i,t} \)| 0.3241         | 0.3355           | 0.0624                | 0.0814                   |
|              | (1.29)           | (1.36)           | (0.18)                | (0.28)                   |
| \( AR_{i,t-1} \)| -0.0091***     | -0.0994***       | -0.2222***            | -0.0686**                |
|              | (-3.63)          | (-3.62)          | (-3.62)               | (-2.56)                  |
| \( Constant \)| -0.0284         | -0.0317          | -0.0424               | -0.0172                  |
|              | (-1.32)          | (-1.52)          | (-1.33)               | (-0.69)                  |
| Country FE   | Yes              | Yes              | Yes                   | Yes                      |
| # of obs     | 7693             | 7693             | 1727                  | 5966                     |
| Adj. \( R^2 \)| 0.0149          | 0.0175           | 0.0527                | 0.0152                   |
| \( \phi_3 \) minus \( \phi_2 \)| N/A             | 0.2168*          | 0.0567                | 0.2583***                |
|              |                  | (1.93)           | (0.23)                | (2.00)                   |
Table 3: Global Stock Market Reactions on the First Day of Clinical Trials of Vaccines Developed in Different Countries

The table reports the empirical estimates of regression equation (1); this regression is reported in Column (2) of Table 2, except that in the present table, \( D_{j_{1,2,3},t} \) is replaced with \( US_{j_{1,2,3},t} \) in Column (1), \( China_{j_{1,2,3},t} \) in Column (2), and \( Others_{j_{1,2,3},t} \) in Column (3). The last row reports the differences between the loading on the generic \( D_{3,t} \) and \( D_{2,t} \) dummy variables. *, **, *** denote significance levels at 10%, 5%, and 1%, respectively.

|                | (1)          | (2)          | (3)          |
|----------------|--------------|--------------|--------------|
| \( US_{1,t} \) | 0.3418**     | -0.0698      | -0.0381      |
| (2.39)         | (-0.60)      | (-0.55)      |
| \( US_{2,t} \) | -0.1157      | 0.3639***    | 0.3968***    |
| (-1.01)        | (4.03)       | (4.20)       |
| \( US_{3,t} \) | 0.6584***    | 0.5889***    | 0.7391***    |
| (4.72)         | (6.43)       | (4.58)       |
| \( VIX_t \)   | 0.0063       | 0.0065       | 0.0067       |
| (1.45)         | (1.50)       | (1.52)       |
| \( BBsprd_t \) | 0.4086***    | 0.3788***    | 0.4470***    |
| (4.89)         | (4.76)       | (4.70)       |
| \( Pct\_cases_{i,t} \) | -0.6018*** | -0.5859*** | -0.5952*** |
| (4.01)         | (-3.99)      | (-4.05)      |
| \( Pct\_deaths_{i,t} \) | 0.3201      | 0.3208       | 0.3416       |
| (1.25)         | (1.28)       | (1.38)       |
| \( AR_{i,t-1} \) | -0.0982*** | -0.0989***  | -0.1004***  |
| (3.61)         | (-3.60)      | (-3.67)      |
| \( Constant \) | -0.0215      | -0.0273      | -0.0185      |
| (-1.03)        | (-1.31)      | (-0.93)      |
| Country FE    | Yes          | Yes          | Yes          |
| # of obs      | 7693         | 7693         | 7693         |
| Adj. \( R^2 \) | 0.0161       | 0.0167       | 0.0163       |
| \( \phi_1 \) minus \( \phi_2 \) | 0.7742***    | 0.2250*      | 0.3423**     |
| (3.53)         | (1.77)       | (2.06)       |

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Table 4: Robustness Check after Excluding Phase 1

In Panel A, we report the key parameters of the modified panel regression equation (1) when the $D_{1,t}$ dummy variable is omitted. In Column (1), we run the panel regression on all 49 countries, and in Columns (2) and (3), we partition the sample observations into 11 vaccine developers and 38 non-vaccine developers. In Panel B, we rerun the modified panel regression equation (1) without the $D_{1,t}$ dummy variable on all 49 countries, and $D_{j(t)}$ is replaced with $US_{j(t)}$ and then with $China_{j(t)}$ and $Others_{j(t)}$ separately. The “$\phi_3$ minus $\phi_2$” row reports the coefficient differences between $D_3,t$ and $D_2,t$. *, **, *** denote significance levels at 10%, 5%, and 1%, respectively.

| Panel A: $D_{1,t}$ dummy variable is omitted | 49 countries (1) | 11 vaccine developers (2) | 38 non-vaccine developers (3) |
|---------------------------------------------|-----------------|--------------------------|-----------------------------|
| $D_{2,t}$                                    | 0.2517***       | 0.2524**                 | 0.2470***                   |
|                                            | (5.26)          | (2.85)                   | (4.22)                      |
| $D_{3,t}$                                    | 0.5207***       | 0.4392**                 | 0.5364***                   |
|                                            | (6.03)          | (2.62)                   | (5.08)                      |
| $\phi_3$ minus $\phi_2$                      | 0.2690***       | 0.1868                   | 0.2894***                   |
|                                            | (3.22)          | (1.40)                   | (2.83)                      |

| Panel B: $D_{1,t}$ dummy variable is omitted and $D_{j(t)}$ is redefined |
|-------------------------------------------------|-----------------|--------------------------|-----------------------------|
| $D_{j(t)}$ is replaced with $US_{j(t)}$ (1) | $D_{j(t)}$ is replaced with $China_{j(t)}$ (2) | $D_{j(t)}$ is replaced with $Others_{j(t)}$ (3) |
| $D_{2,t}$                                    | 0.1047          | 0.3202***                | 0.3672***                   |
|                                            | (1.49)          | (4.21)                   | (4.88)                      |
| $D_{3,t}$                                    | 0.5362***       | 0.5919***                | 0.7425***                   |
|                                            | (4.51)          | (6.50)                   | (4.64)                      |
| $\phi_3$ minus $\phi_2$                      | 0.4315***       | 0.2717**                 | 0.3753***                   |
|                                            | (3.02)          | (2.46)                   | (2.71)                      |
### Table 5: Robustness Check on Non-vaccine Developers

The table reports the key parameters of the panel regression equation (1) but limits the regressions to 38 non-vaccine developers, with the parenthesized t-statistics computed using standard errors clustered at the country level. In Column (1), we run the panel regression on 16 developed economies, and in Column (2), we repeat the analysis on 22 emerging economies. In total, 38 economies make up the non-vaccine developer group. The last row reports the coefficient differences between $D_{3,t}$ and $D_{2,t}$. *, **, *** denote significance levels at 10%, 5%, and 1%, respectively.

|                      | 16 developed economies (1) | 22 emerging economies (2) |
|----------------------|---------------------------|----------------------------|
| $D_{1,t}$            | 0.2820***                 | -0.3123**                  |
|                      | (4.67)                    | (-2.29)                    |
| $D_{2,t}$            | 0.2186**                  | 0.3554**                   |
|                      | (2.31)                    | (2.64)                     |
| $D_{3,t}$            | 0.3966***                 | 0.6142***                  |
|                      | (4.64)                    | (3.51)                     |
| $\phi_3$ minus $\phi_2$ | 0.1780*                  | 0.2588                     |
|                      | (1.85)                    | (1.22)                     |
Table 6: Robustness Check Using Three-Day Event Window

The table reports the key parameters of the panel regression equation (1) when the $D_{j,t}$ dummy variable is omitted. The $D_{j-2,3,t}$ dummy variables take the value of 1 over a three-day [-1, +1] event window surrounding the first day of phase $j$, and 0 otherwise. In Column (1), we run the panel regression on all 49 countries, and in Columns (2) and (3), we partition the sample observations into 11 vaccine developers and 38 non-vaccine developers. The “$\phi_3$ minus $\phi_2$” row reports the coefficient differences between $D_{3,t}$ and $D_{2,t}$. *, **, *** denote significance levels at 10%, 5%, and 1%, respectively.

|                  | 49 countries (1) | 11 vaccine developers (2) | 38 non-vaccine developers (3) |
|------------------|------------------|---------------------------|-------------------------------|
| $D_{2,t}$        | 0.1103***        | 0.1449                    | 0.0897**                     |
|                  | (2.90)           | (1.24)                    | (2.21)                       |
| $D_{3,t}$        | 0.2005***        | 0.3139**                  | 0.1498**                     |
|                  | (3.38)           | (3.15)                    | (2.10)                       |
| $\phi_3$ minus $\phi_2$ | 0.0902          | 0.1690                    | 0.0601                       |
|                  | (1.31)           | (1.53)                    | (0.74)                       |
Figure 1: Cumulative Wealth of $1 Invested in Different Stock Markets

The figure shows the cumulative wealth of $1 invested in different stock markets from January 2, 2020, to August 7, 2020. For brevity, the figure only shows the investment in five key stock market indices: S&P 500, FTSE 100, DAX, Nikkei 225, and Hang Seng Index. The shaded region covers the period from February 11 (when the WHO labeled the disease as “COVID-19”) to April 2 (when a million infections were reported worldwide).