A Shot in the Arm: The Effect of COVID-19 Vaccine News on Financial and Commodity Markets*

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April 13, 2023

Forthcoming in The Financial Review

Abstract

We analyze the impact of COVID-19 vaccine announcements by leading vaccine companies on the financial and commodity markets from January to December 2020. We show that the vaccine announcements had varied and economically significant impacts on asset prices. The announcements moved interest rates, stock markets in the U.S. and numerous other countries as well as commodities used in transportation and some agricultural commodities. We show that the stock and commodity markets that experienced larger declines at the beginning of the pandemic receive a larger boost from good vaccine news. We also find that the vaccine news affects stock returns through changes in the expectations of the corporate cash flows and the expected equity risk premium.

Keywords: COVID-19 vaccine; stock market; interest rates; commodities
JEL classification: F31; G12; G14; G15; I10; Q41

*We thank the editors, two anonymous referees, Aaron Burt, Adrian Fernandez-Perez, Andrea Heuson, Raquel Lopez, Yueliang Lu, Alessio Piccolo, Peter von Allmen, and participants at the 2021 Liberal Arts Macro Conference, 2022 Financial Markets and Corporate Governance Conference, 2022 Commodity and Energy Markets Association Conference, 2022 Western Economic Association International Conference, 2022 FMA European Conference, 2022 FMA Annual Meeting, 2022 Southern Finance Association Conference, 2022 Southern Economic Association Conference, 2023 Eastern Finance Association Conference, and participants in the seminars at the Auckland Centre for Financial Research, International Capital Market Association Centre at the University of Reading, Skidmore College, and West Virginia University for their helpful comments. We also thank Zejun Jiang for assistance with collecting data about vaccine announcements from China and Shanxiang Yang for assistance with collecting data about COVID-19 cases.

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1 Introduction

to announcements about the development of the vaccines. The vaccine news influences investor expectations about the future course of the pandemic. Understanding the reaction of the financial and commodity markets to the vaccine news is therefore useful for predicting the economic impact of future pandemics and calibrating policy responses to them. More specifically, our paper answers four research questions that have not been studied in the previous literature.

First, when the COVID-19 crisis started in March 2020, the Federal Reserve responded to the pandemic-induced recession by an extremely accommodative monetary policy, cutting its benchmark policy rate to zero in two unscheduled meetings.[2] The Federal Reserve subsequently stated that its policy decisions would depend on the course of the pandemic. Development of effective vaccines influences the course of the pandemic. Therefore, our first research question asks how the COVID-19 vaccine news, and thus the expected course of the pandemic, affect expectations of future monetary policy. Because interest rate changes affect stock prices, analyzing the effect of vaccine news on interest rates helps us better understand how the news about the COVID-19 vaccines influences the stock market, which is the focus of our next question.

Second, through what channels does information about the expected course of the pandemic influence the stock market? Boyd, Hu, and Jagannathan (2005) note that economic news influences stock prices by affecting expectations of future corporate earnings, the risk-free interest rate, and the equity risk premium. All these three types of information could play a role in the market reaction to the COVID-19 vaccine news: The pandemic has affected corporate earnings in many industries, the Federal Reserve responded by reducing the risk-free interest rates, and judging from the large increase in volatility during the stock market crash of February-March 2020 (Baker et al., 2020), it is also likely that the pandemic affected investor risk appetite and, therefore, the equity risk premium.

The third research question that we answer is to what extent the reaction to vaccine

[2] Clarida, Duygan-Bump, and Scotti (2021) present the timeline of the Federal Reserve's policy response.

news di ers across international stock markets. Economies of di erent countries have been a ected di erently by the pandemic. We examine whether there are substantial di erences between stock market reactions to COVID-19 vaccine news in North and South America, Europe, Africa, Asia, and Australia. Several countries in the Asia-Paci c region adopted the \zero-COVID" strategy and their economies were less a ected by the spread of the disease, perhaps attenuating the importance of the vaccine news for these economies. At the same time, these countries are integrated into the global economy, giving their economies exposure to COVID-19 in spite of the zero-COVID strategy. Therefore, the extent to which the stock

tion of the nominal interest rates increases with the bond maturity and operates through the expected real interest rates (rather than through expected in ation). The positive e ect of vaccine news on the expected real interest rates shows that expectations of monetary policy depend in part on the course of the pandemic.[4] Second, we nd that the positive response of stock returns to the vaccine news is driven by information about both future corporate earnings and equity risk premium (but not the risk-free rate). Third, the impact of the vaccine news on the international stock markets is far from uniform: the stock markets in the U.S., U.K., EU, Canada, Mexico, Brazil, South Africa, and Nigeria react to the announcements but stock markets in Asia and Australia do not. Fourth, in the commodity markets, commodities used in transportation (crude oil, gasoline, corn, soybeans, and soybean oil) and agricultural commodities cocoa, co ee, and cotton react to the vaccine announcements while precious metals gold and silver, construction commodities copper and lumber, and agricultural commodity wheat are una ected. We show that the heterogeneity in the reaction of stock and commodity markets to the vaccine announcements is related to what happened in the markets at the beginning of the pandemic: the markets that experienced larger declines at the beginning of the pandemic receive a larger boost from good vaccine news.

The e ect of the announcements on the interest rates, stock prices, and commodities is economically signi cant. For example, the S&P500 index returns were on average higher by about 0.9% on the 57 days with important vaccine news than on other days, adding up to an increase of approximately 50% during our sample period. The total S&P 500 index return was approximately 13% in this period, which shows that the e ect of the announcements more than o sets negative average returns recorded on days without the announcements.

The remainder of the paper is organized as follows. The next section reviews the related literature and highlights our four contributions. Section 3 describes the vaccine announcement data and the market data. After presenting our methodology, Section 4 reports and

[4] Hanson and Stein (2015) show that monetary policy decisions have a strong e ect on long-term real interest rates. This nding, along with our nding that real rates are a ected by vaccine news, suggests that vaccine news a ects expectations of future monetary policy.

discusses our results. Section 5 discusses robustness checks where we test for potential effects of other events unrelated to our vaccine announcements. Section 6 briefly concludes.

2 Literature Review

Numerous papers have begun the study of how the COVID-19 pandemic affected the economy and financial markets without focusing on the effect of the vaccine news. For example, Baker et al. (2020) document an unprecedented negative reaction of the stock market. The reaction of the stock market is also studied by Alfaro, Chari, Greenland, and Schott (2020), Ashraf (2020), Papadamou, Fassas, Kenourgios, and Dimitriou (2020), Zaremba, Kizys, Aharon, and Demir (2020), Zhang, Hu, and Ji (2020), Ding, Levine, Lin, and Xie (2021), and O'Donnell, Shannon, and Sheehan (2021). Yarovaya, Matkovskyy, and Jalan (2022) find that COVID-19 impacted not only stock markets but also 10-year bonds, precious metals, and cryptocurrencies.

Several papers study the role of the COVID-19 vaccine. Hong, Wang, and Yang (2021) use an epidemiological model with transmission-rate shocks in an asset-pricing framework that includes disease mitigation and vaccine arrival to quantify the economic damage of COVID-19. Hong, Kubik, Wang, Xu, and Yang (2021) estimate a damage function utilizing revisions of industry earnings forecasts and show that the economic damage is nonlinearly affected by the vaccine. Sockin (2020) builds a macroeconomic model where households are averse to uncertainties about health and discusses that vaccines can affect stocks via investor risk aversion and equity risk premium. O'Donnell, Shannon, and Sheehan (2022) study nine international stock indices as well as a world stock index and find that positive changes in these indices are associated with growth in the COVID-19 vaccination programs.

The three studies most related to our paper are Acharya, Johnson, Sundaresan, and Zheng (2021), Chan, Chen, Wen, and Xu (2022), and Grab, Kellers, and Mezo (2021). Acharya et al. (2021) create a \vaccine progress indicator," a continuous variable based on

progress of the vaccines and related news, document the relation between the expected time to distribution of the vaccine and the U.S. stock returns and show that this relationship is stronger in industries that are more a ected by the pandemic; they also estimate the value of a vaccine in an asset-pricing framework. Chan et al. (2022) expand the analysis to 50 stock markets and report results aggregated for two groups of countries: a group of countries developing vaccines and a group of countries not developing vaccines, with further distinction between developed and emerging economies within the groups. They show a heterogeneous impact of vaccine news on the rst day of the trials: the stock market reaction for the developed economies group is stronger than that of the emerging economies. Grab et al. (2021) use the Good Judgement website forecasts of when the vaccine will become available and report that increased beliefs in the vaccine availability positively a ected stocks of some industries more than other industries, with the Euro area experiencing larger gains than the U.S.

Our paper contributes to this literature in four ways. First, we analyze the interest rate markets which allows us to show how the COVID-19 vaccine news a ects expectations of future monetary policy. Second, as discussed in the Introduction, we provide an explanation of the U.S. stock market results: our decomposition of the aggregate stock market returns shows that the price impact is driven by both the expected corporate earnings and the equity risk premium (but not the risk-free rate). Third, we provide results for a larger set of stock markets while using all as well as selected important COVID-19 vaccine announcements by leading vaccine companies; this expands Acharya et al. (2021) who study only on the U.S. stock market while using the vaccine progress indicator and Chan et al. (2022) who report results for a group of countries developing vaccines and a group of countries not developing vaccines in response to vaccine announcements only at the beginning of clinical trials. We contribute to the literature by showing that important announcements about the vaccine discovery, development of clinical trials, government authorization as well as funding impacted the nancial markets. The vaccine announcements a ected stock markets in the

U.S., U.K., EU, Canada, Mexico, Brazil, South Africa, and Nigeria while the stock markets

announcements were released on Sundays and we therefore place them in the following Mondays. On some days there is more than one announcement. Column \Day" shows how multiple announcements combine into a single trading day when more than one announcement occurs on the same day (or on consecutive days if there are announcements that occur on weekends, on holidays, or after the U.S. stock market closed at 16:00 on the previous trading day such as announcements#17 released at 17:55 on a Thursday and #18 released at 13:07 on a Friday). There are 102 trading days with announcements. Figure 1 shows the timeline of these announcements.

137 announcements bring positive news about the vaccines, such as announcement #7

3-year overnight indexed swaps that indicate what the markets expect the federal funds rate to be in two and three years, respectively.[8]

For stock markets, we include the S&P 500 as the U.S. stock index (and verify the results with Dow Jones Industrial Average (DJIA) and NASDAQ-100 indices). From Europe, we include the European stock market index EuroStoxx600 and indices for the five largest economies that comprise the EuroStoxx600: CAC40 from France, DAX from Germany, FTSE MIB from Italy, IBEX35 from Spain, and FTSE100 from the United Kingdom. From Asia, we include the Asian stock market index S&P Asia 50 and indices for China (Shanghai), Hong Kong (Hang Seng), India (BSE-Sensex), Japan (Nikkei225), and South Korea (KOSPI200). We also include indices for six other stock markets: FTSE/JSE Top 40 for South Africa and NSE 30 for Nigeria that are the two largest stock markets in Africa; Bovespa for Brazil, which is the largest stock market in South America; Toronto TSX 300 for Canada and Dow Jones Mexico for Mexico as the remaining two stock markets in North America; and S&P/ASX 200 index for Australia.

For commodity markets, we include energy, precious metal, construction as well as agricultural commodities. In energy commodities, we include the three largest markets:[9] crude oil, natural gas, and gasoline. In metal commodities, we also include the three largest commodity markets: gold, copper, and silver. Gold and silver are the two largest precious metal markets and copper is the largest base metal market. Since copper is predominantly used in the construction industry (Garside, 2021), we also include lumber as another construction commodity. In agricultural commodities, we include the four largest commodity markets: corn, soybeans, soybean oil, and wheat. In addition, we include cocoa, Arabica coffee, and cotton. We use futures prices for the commodities. Because futures contracts become increasingly illiquid close to their expiration (which is especially the case in lumber that is less liquid than the other commodity markets), we use the next-to-maturity contracts when

[8] Lloyd (2021) shows that overnight indexed swap rates reliably measure the interest rate expectations.

[9] See the Chicago Mercantile Exchange website (https://www.cmegroup.com) for the commodity futures market size information.

the results for the U.S. stock market. Section 4.2 then answers our four research questions related to the monetary policy, explanation for the U.S. stock market reaction, international stock markets, and commodity markets.

4.1 Methodology and Empirical Results for the U.S. Stock Market

In this section we explain our methodology for analyzing the impact of the vaccine announcements and show results for the U.S. stock market. We begin by estimating the following equation using the ordinary least squares (OLS):

$$R_t = \beta_0 + \sum_{l=1}^{L} \beta_l R_{t-l} + \gamma \mathbb{1}_t + \varepsilon_t; \tag{1}$$

where R_t is the S&P 500 index log return on day t, β_0 is a constant, and the return lags account for possible autocorrelation of returns. The optimal number of return lags, L, is determined with the Schwarz information criterion, resulting in seven lags.[10] $\mathbb{1}_t$ is an indicator variable that takes on the value of one if there is an announcement about any of the four vaccines on that day and zero otherwise.[11] Since our sample includes only positive news about the vaccine development as described in Section 3.1, a positive coefficient on the announcement indicator variable, γ, means that the good news increases the return.

Column (1) of Table 2 reports results for our sample period from January 22, 2020 to December 31, 2020. The coefficient on the announcement indicator variable is statistically significant, which means that the stock market returns are higher on days with the vaccine announcements. The stock market looks to the vaccine announcements in hopes of the

[10] The high number of lags in our sample period is driven by the stock market crash at the beginning of the pandemic. We verify that the number of lags does not affect our results by estimating equation (1) with zero, one, and two lags. The results, available upon request, are similar to the results in Table 2.

[11] Gu and Hibbert (2021) use a similar methodology to examine the effect of changes in the probability of Brexit on financial and commodity markets.

economy rebounding, which increases the stock prices.[12,13]

[Insert Table 2 here]

Our sample contains all announcements about the vaccines published by the institutions developing the vaccines on their websites. However, it is conceivable that some announcements are more important and therefore impact the markets more strongly. We select announcements if they pertain to one of the following five selection criteria: 1) funding for the vaccine development (10 announcements such as announcements #1 and #3), 2) research and discovery stage or three phases of clinical development[14] (40 announcements such as announcements #4 and #6), 3) initiation of collaboration between institutions developing the vaccines (2 announcements #8 and #24), 4) government supply agreements signed with the U.S. or the European Commission (13 announcements such as announcements #36 and #47), or 5) government authorization (5 announcements such as announcements #114 and #124).

In many announcements, the content is clear from the title. For example, the title of announcement #4 "Moderna Ships mRNA Vaccine Against Novel Coronavirus (mRNA1273) for Phase 1 Study" is clearly about phase 1 of the vaccine development. In some announce-

[12] As a robustness check, we estimated equation (1) with additional terms for leads and lags of Ann_t to test for any potential impact that the vaccine announcements might have in the days preceding or following the announcements. The results (available in the Online Appendix) show that the return leads and lags are not significant, which means that the vaccine announcements do not affect prices in the days preceding or following the announcements.

[13] In addition to analyzing the impact of the vaccine announcements on the stock market index, we analyze the impact on stock prices of the companies that developed the vaccines. The results (available in the Online Appendix) show that the vaccine announcements moved stock prices of all four companies involved

ments, however, the content is unclear from the title, for example, announcement #6 title \P zer Outlines Five-Point Plan to Battle COVID-19" . We read the entire text of all announcements to understand the content and classify the announcements accordingly. While reading the announcements, we also identi ed eight announcements that were duplicates of previous announcements in the sense that important information from previous announcements was to a great extent being repeated. Following the e cient market hypothesis, we did not include these duplicate announcements among our selected announcements since information is most impactful when received by the markets for the rst time.[15]

There are then 70 announcements meeting the above ve selection criteria, comprising 12, 21, 18, and 19 announcements about the Johnson & Johnson, Moderna, Oxford-AstraZeneca,

The coefficient on the vaccine announcement variable is more than twice as large as the coefficient in Column (1): 0.878 compared to 0.409, indicating that the selected announcements are indeed especially impactful[16]. The remainder of the paper therefore uses this set of impactful announcements in the analysis explaining the U.S. stock market results in Section 4.2.2 and in the analysis of other markets in Sections 4.2.1, 4.2.3, and 4.2.4.

To gain a perspective on the economic significance of the Table 2 results, it is useful to note that all intercept estimates are negative, although statistically insignificant. This indicates that the mean stock market returns were negative on days without vaccine news. The S&P 500 index increased by approximately 13% in our sample period. According to our regression results, the average stock returns were positive only on the vaccine announcement days. Multiplying the coefficient estimate (0.878) by the number of trading days with the important vaccine announcements (57) indicates that the cumulative U.S. stock market return on the important vaccine announcement days was approximately 50%, which more than offsets the negative returns incurred on days without the important vaccine announcements and translates into trillions of dollars of shareholder value[17].

We also conduct an industry-level analysis. Using data for returns on 12 industry portfolios from Kenneth French's website[18], we find that the coefficient on the announcement indicator variable is statistically significant at 1% level in regressions for all 12 industries. Industries most affected by the pandemic have the largest coefficient estimates: The coefficient magnitude ranges from 0.816 for Telecommunications that was not majorly impacted by the pandemic to 2.758 for Energy that was severely impacted. These results are not tabulated

[16] As a robustness check, we analyze the impact on the DJIA and NASDAQ-100 indices. The coefficients on the announcement indicator variable for these indices are also statistically significant at 1% level and are slightly higher (0.933 and 0.900, respectively, compared to 0.879 for the S&P 500 in Column (2) of Table 2). These results are available upon request.

[17] This calculation follows the methodology of Lucca and Moench (2015) who measure how much the daily S&P 500 return was impacted by the Federal Open Market Committee (FOMC) meetings. Lucca and Moench (2015) regress the return on an indicator variable taking on the value of one if there is an FOMC meeting and the value of zero if there is no FOMC meeting and then add up the average returns on the announcement days (measured by the coefficient on the FOMC meeting indicator variable) to compute the total impact that the FOMC meetings have on the return. Following this methodology, we multiply our

for conciseness but are available upon request.

4.2 Empirical Results for Our Four Research Questions

4.2.1 How Does Vaccine News A ect Interest Rates?

When the COVID-19 crisis started in March 2020, the Federal Reserve cut its benchmark policy rate to zero in two unscheduled meetings. The Federal Reserve subsequently stated that its policy decisions would depend on the course of the pandemic. Development of e ective vaccines in uences the course of the pandemic. This section therefore focuses on our rst question: To what extent does the COVID-19 vaccine news, and, therefore, the expected course of the pandemic, a ect expectations of future monetary policy? This question is important in its own right. Furthermore, since monetary policy a ects the equity market, answering this question helps us explain what drives the reaction of stock prices to vaccines news.

We analyze the U.S. Treasury yields and overnight indexed swap rates with various maturities to answer this question. We again determine the number of lags for each market using the Schwarz information criterion, which results in zero lags for all markets except for two lags for the 2-year overnight indexed swap, three lags for the 3-year overnight indexed swap, and eight lags for the 2-year Treasury; the lag coe cient estimates are again not reported for conciseness but are available upon request. We then estimate equation (1) for each market using the set of impactful vaccine announcements used in Column (2) of Table 2.

Table 3 reports the results. The vaccine announcements impact all maturities of the Treasuries. The positive e ect of the vaccine news likely re ects expectations of tighter monetary policy as the pandemic abates and the economy recovers with the aid of the vaccines. The coe cients increase with maturity, ranging from less than a basis point in the 2-year Treasury yield to two and a half basis points in the 30-year Treasury yield. According to the expectations theory of the interest rate term structure, the bond yield is determined by the expected short-term rates during the life of the bond. Since in our sample period most

investors expected the short-term rates to stay at the zero lower bound for most of the next two years, the response of the 2-year Treasury is marginal.[19] However, if market participants expect the Federal Reserve to start increasing the federal funds rate or reducing its bond purchases before the bond maturity date, the rates will respond to news that are important for monetary policy decisions. That is the case in our data where the impact increases with maturity, with the higher coe cients on the longer maturities re ecting investors expecting a lift-o from the zero lower bound as a part of the expected monetary policy tightening. The estimated impacts of vaccine news are economically signi cant. For example, for the 5-year, 10-year, and 30-year Treasury yields, these estimates are close to half of the standard deviation of daily yield changes shown in Table 1.

[Insert Table 3 here]

This nding is supported by the results for the overnight indexed swaps (OIS) that indicate what the markets expect the federal funds rate to be at the OIS maturity. For

The coe cients estimates are positive but not statistically signi cant. This indicates that vaccine news a ects interest rates primarily by moving expectations of the real rates. These results are not tabulated to save space but are available upon request.

4.2.2 What Drives the Reaction of Stock Prices?

Section 4.1 shows that the vaccine announcements move the stock market. Through what channels does information about the expected course of the pandemic in uence the stock market? This section answers this question. News announcements move stock prices if the announcements convey information about the expected corporate cash ows or the expected return (consisting of the risk-free interest rate and the equity risk premium) used to discount the cash ows (for example, Boyd et al. (2005)). We investigate which of these three channels drives the reaction of the stock markets to the vaccine announcements by decomposing the aggregate stock returns. Introduction of e ective vaccines alters the expected course of the pandemic. It is conceivable that stocks of rms in some industries, for example,

time series of the aggregate cash flow news and the aggregate discount rate news, we follow Atilgan, Bali, and Demirtas (2015) and estimate the first-order vector autoregression (VAR). Results of this VAR estimation are provided in the Online Appendix.

We then estimate OLS regressions of the estimated cash flow news and discount rate news on the vaccine news indicator variable. Table 4 presents the results. The cash flow news component responds positively to good news about vaccines, with the coefficient estimate of approximately 0.34%, significant at the 10% level, indicating that the expected cash flows increase in response to good news about the vaccine.

[Insert Table 4 here]

The coefficient on the discount rate news is negative (-0.59%), significant at the 1% level. This means that the discount rate news component falls in response to good news about the vaccines. The discount rate is a sum of the risk-free rate and the equity risk premium. We therefore further analyze which of these two channels affects the discount rate. Our results for the interest rates in Table 3 show that the risk-free rate increases in response to positive vaccine news. The negative coefficient estimate for the discount rate news in Table 4 is therefore driven by the equity risk premium decreasing in response to positive vaccine news (rather than being driven by the risk-free rate).

This conclusion about the equity risk premium decreasing in response to positive vaccine news is confirmed by our analysis of the Chicago Board Options Exchange's (CBOE) Volatility Index (VIX). We compute the change in the VIX, i.e., $VIX_t - VIX_{t-1}$. We determine the optimal number of lags using the Schwarz information criterion, which results in three lags. We then estimate equation (1) using the VIX change as the dependent variable. The coefficient on the announcement indicator variable is statistically significant at 1% level. As expected, it has a negative sign, which is the opposite sign compared to the coefficient for the S&P 500 returns in Table 2 because it is well known that VIX changes are negatively correlated with stock returns. This finding supports our result showing that the negative coefficient estimate for the discount rate news in Table 4 is driven by the equity premium

decreasing in response to positive vaccine news. The negative coe cient for the VIX supports this conclusion because the VIX is a high-frequency proxy for the equity risk premium (Martin, 2017).

Taken together, these results mean that the positive response of stock returns to the vaccine news documented in Table 2 is driven by information about future corporate cash ows and equity risk premium (but not the risk-free rate). This analysis helps explain, for example, why the broad stock indices declined dramatically and experienced extreme volatility at the beginning of the pandemic (Baker et al., 2020). Understanding the channels through which the pandemic in uences equity prices is useful for policy makers trying to

for markets in other countries. Consider, for example, the stock market in France. That stock market has trading hours from 9:00 Central European Time (CET) to 17:30 CET. The announcement released at 12:00 Eastern Time (which is 18:00 CET due to a six-hour di erence between the ET and CET) arrives after the French stock market trading hours and, therefore, the announcement date is the following trading day.

We also determine the number of lags for each market using the Schwarz information criterion, which results in zero lags for all stock indices except for the stock indices in Brazil with one lag; Italy, Nigeria, and Spain with two lags; Australia with three lags; and Canada with seven lags. The lag coe cient estimates are again not reported for conciseness but are available upon request.

We estimate equation (1) for each market using the set of impactful vaccine announcements used in Column (2) of Table 2. Table 5 Panel a) reports the results for the European stock markets. The coe cient on the vaccine announcement variable is signi cant. The magnitude of the coe cients ranges from 0.751 in Spain to 0.849 in Italy and compares to the coe cient of 0.878 for the U.S. in Column (2) of Table 2.

[Insert Table 5 here]

Interestingly, the reaction of the stock markets in Panel b) and c) is more varied. The vaccine announcements are not signi cant in the stock markets in Asia in Panel b) of Table 5 except for South Korea that is signi cant at the 10% level. In Panel c), the stock markets in Brazil, Mexico, and Canada react to the announcements, the stock markets in Nigeria and South Africa show statistical signi cance at 10% level, and the stock market in Australia does not react to the announcements. What might explain this heterogeneity in the reaction across the stock markets? The following analysis investigates this question.

We estimate equation:

$$R_{i;t} = \quad _0 + \quad _1 R_{i;t-1} + \quad _1 \blacksquare \quad _t + \quad _2 \blacksquare \quad _t \quad \blacksquare \quad \quad _i + \quad _i + \quad _{i;t}; \qquad (3)$$

where in comparison to equation (1), there are two modi cations. First, instead of estimating

the model for an individual stock market as in equation (1), we include all 19 stock markets (18 stock markets shown in Table 5 and the U.S. stock market shown in Table 2) in a combined panel data set. $R_{i;t}$ is then the log return for the given market i on day t and $_i$ stands for the market-speci c random e ects (i.e., cross-section random e ects). Second, to measure the extent to which the market was a ected by the initial pandemic-related crisis, we include a variable $_i$, which is the log return for the given market i from January 31, 2020 to March 22, 2020[20]. We standardize the $_i$ variable by subtracting the cross-sectional mean and dividing by the standard deviation of the return. To

with standard errors corrected for correlations across markets.[22] We determine the optimal number of lags for this panel data set, which turns out to be one lag. The lag coe cient estimate is again not reported for conciseness but is available upon request. There are 205 trading days and 19 markets. This is an unbalanced panel because some markets are closed on some days due to holidays as discussed above; the total number of panel observations is 3,735.

then not as impactful as in the U.S. and Europe where they were perceived as game-changers for the dire health situation. In addition, some countries announced that they would not be using the Johnson & Johnson, Moderna, Oxford-AstraZeneca, and P zer-BioNTech vaccines

commodities (crude oil and gasoline) and several agricultural commodities (cocoa, co ee, corn, cotton, soybeans, and soybean oil) but this impact is not shared by one energy commodity (natural gas), precious metals (gold and silver), construction commodities (copper and lumber), and one agricultural commodity (wheat). What drives this heterogeneity in results? We repeat the panel regression analysis conducted in Section 4.2.3. Column (2)

roles in the economy. For example, gold, in addition to being a commodity used in industrial production, played the role of a safe haven asset as well as a hedge for the equity markets at various phases of the COVID-19 recession (Akhtaruzzaman, Boubaker, Lucey, & Sensoy, 2021). Gold is also viewed as an in ation hedge and its prices may be driven by investor psychology, exacerbated by price pressure from large gold holdings in gold exchange-traded funds (ETF) (Erb, Harvey, & Viskanta, 2020). It is perhaps due to a combination of these factors that the vaccine announcements did not impact the gold price.

5 Robustness Checks

We already noted in Section 3.1 that our results are robust to including a negative announcement and in Secton 4.1 that our results for the U.S. stock market are robust to the choice of the stock market index (Dow Jones Industrial Average and NASDAQ-100 indices rather than the S&P 500 index), the number of lags (zero, one, and two lags rather than the seven lags determined by the Schwarz information criterion), and any potential price moves that might occur on days preceding or following the announcements. This section discusses additional robustness checks.

One potential concern about our equation (1) is that the results might be driven by other events unrelated to our vaccine announcements. Therefore, we conduct robustness checks to test whether our results for the U.S. stock market are robust to such other events. Speci cally, we control for announcements about vaccines developed in China, the U.S. macroeconomic news announcements, a general measure of COVID-19 related uncertainty, and the U.S. daily COVID-19 cases. Our results (available in the Online Appendix) are robust in all these tests.

While we cannot test for all important news that arrived during our sample period (for example, news about the U.S. presidential elections, climate policy regulations, infrastructure spending, etc.), we are encouraged to know that for this news to be an omitted variable biasing our results upward, it would have to be systematically released on our vaccine an-

nouncement days (rather than both on announcement and non-announcement days) and the news would have to be systematically positive for the markets (rather than the news being

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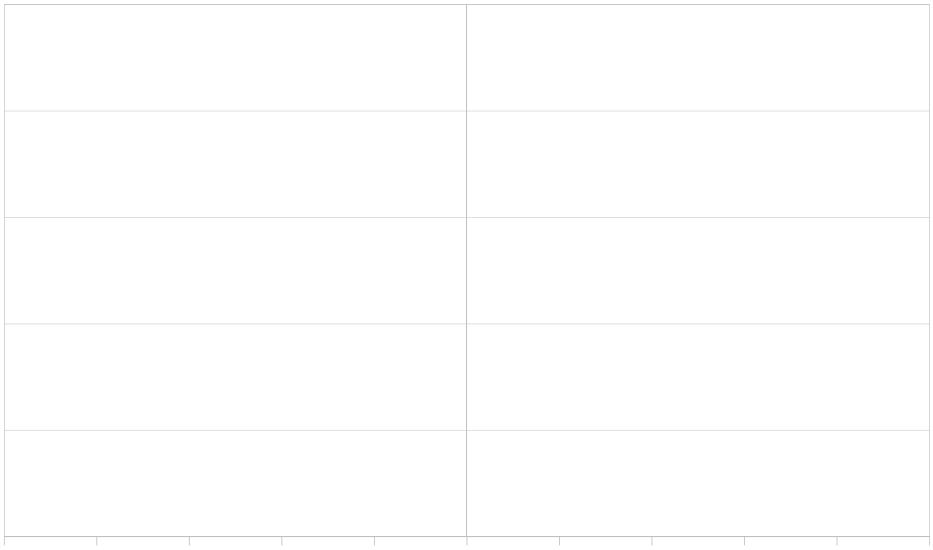
Figure 1: Timeline of Vaccine Announcements

This gure shows the cumulative number of vaccine announcements (indicated by markers) for the four vaccines from January 23, 2020 to December 31, 2020.

Figure 2: S&P 500 Return Densities



This figure shows kernel densities of the S&P 500 log returns on 57 days with impactful vaccine announcements and on the other 183 days. The bandwidth is selected using the Sheather and Jones (1991) method.

Table 1: Summary Statistics

Market Type	Market	Median	Mean	Stnd Dev	Min	Max	Obs.
Interest rates	2-year Treasury	0.000	-0.006	0.03	-0.25	0.12	238
	5-year Treasury	0.000	-0.005	0.04	-0.22	0.17	238
	10-year Treasury	0.000	-0.004	0.06	-0.21	0.29	238
	30-year Treasury	0.000	-0.002	0.07	-0.31	0.29	238
	2-year overnight indexed swap	-0.001	-0.005	0.12	-1.17	1.06	246
	3-year overnight indexed swap	-0.001	-0.005	0.12	-1.12	1.00	247
Stocks	US - S&P500	0.24	0.05	2.24	-12.77	8.97	240
	Europe - EuroStoxx600	0.11	-0.02	1.81	-12.19	8.17	244
	France - CAC40	0.03	-0.04	2.12	-13.10	8.28	243
	Germany - DAX	-0.01	0.01	2.15	-13.06	10.41	240
	Italy - FTSE MIB	0.12	-0.03	2.20	-16.14	8.55	241
	Spain - IBEX35	0.05	-0.07	2.21	-15.15	8.23	243
	U.K. - FTSE	0.06	-0.07	1.91	-11.51	8.67	240
	Asia - S&P50 Asia	0.25	0.11	1.60	-5.35	6.86	245
	China - Shanghai Composite	0.11	0.06	1.34	-8.04	5.55	229
	Hong Kong - Hang Seng	0.08	-0.01	1.50	-5.72	4.78	234
	India - BSE-Sensex	0.28	0.06	2.09	-14.10	8.60	237
	Japan - Nikkei 225	-0.01	0.06	1.65	-6.27	7.73	232

Table 2: Impact of Vaccine Announcements on U.S. Stock Market

	(1)	(2)
Announcement	0	

Table 3: Impact of Vaccine Announcements on Interest Rates

	2-year Treasury	5-year Treasury	10-year Treasury	30-year Treasury	2-year OIS	3-year OIS
Announcement	0.006*	0.018***	0.022***	0.025***	0.026***	0.029***
	(0.003)	(0.006)	(0.008)	(0.009)	(0.010)	(0.010)
Constant	−0.005**	−0.009***	−0.009**	−0.008*	−0.015*	−0.016**
	(0.002)	(0.003)	(0.004)	(0.005)	(0.008)	(0.007)
Trading days	237	238	238	238	246	247
Trading days with ann.	56	56	56	56	57	57

This table shows the results of estimating equation (1) that regresses the yields defined as $\text{yield}_t = \text{yield}_t - \text{yield}_{t-1}$ on a constant and an indicator variable that takes on the value of one if there is a vaccine announcement on that day and zero otherwise. We include two lags for the 2-year overnight indexed swap (OIS), three lags for the 3-year OIS, and eight lags for the 2-year Treasury based on the Schwarz information criterion; the lags are not reported for conciseness but are available upon request. The estimation uses the set of vaccine announcements selected as described in Section 4.1. The number of trading days varies across markets because of opening hours and holidays observed in these markets; the 2-year OIS has one missing observation in the FRED data source. The OLS regression is used. The sample period is from January 22, 2020 to December 31, 2020. White (1980) standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Table 4: Impact of Vaccine Announcements on Cash Flow and Discount Rate News

	Cash Flow News	Discount Rate News
Announcement	0.338*	−0.592***
	(0.176)	(0.141)
Constant	−0.125	0.156
	(0.120)	(0.095)

Table 5: Impact of Vaccine Announcements on Other Stock Markets

	Euro Stoxx600	CAC40	DAX	FTSE MIB	IBEX35	FTSE100
Panel a): Stock markets in Europe						
Announcement	0.709***	0.798**	0.805**	0.849***	0.751**	0.778***
	(0.268)	(0.316)	(0.336)	(0.298)	(0.335)	(0.287)
Constant	−0.193	−0.226	−0.189	−0.226	−0.237	−0.256*
	(0.132)	(0.154)	(0.154)	(0.164)	(0.154)	(0.139)
Trading days	244	243	240	241	243	240
Trading days with ann.	58	58	58	58	58	58
	S&P50 Asia	Shanghai	Hang Seng	Nikkei225	KOSPI200	BSE Sensex
Panel b): Stock markets in Asia						
Announcement	0.352	−0.029	0.265	0.006	0.471*	0.242
	(0.244)	(0.177)	(0.234)	(0.260)	(0.269)	(0.317)
Constant	0.023	0.064	−0.076	0.059	−0.001	0.003
	(0.116)	(0.109)	(0.111)	(0.123)	(0.142)	(0.157)
Trading days	245	229	234	232	234	237
Trading days with ann.	58	56	57	58	54	57

Panel c): Other stock markets

Table 6: Heterogeneity in Vaccine Announcement Impact Across Stock and Commodity Markets

	(1) Stock Markets	(2) Commodity Markets
Announcement	0.453***	0.667***
	(0.155)	(0.183)
Announcement*PANDEMIC	0.139**	0.571***
	(0.071)	(0.213)
Constant	0.092	0.048
	(0.091)	(0.096)
Number of time periods (Trading days)	205	202
Number of cross-sections (Markets)	19	14
Total panel observations	3,735	2,795

This table shows the results of estimating equation (3) that regresses the log return,

Table 7: Impact of Vaccine Announcements on Commodity Markets

	Panel a): Energy, precious metal, and construction commodities						
	Crude Oil	Gasoline	Natural Gas	Gold	Silver	Copper	Lumber
Announcement	2.929***	2.227***	0.581	−0.152	−0.289	0.109	0.488
	(0.923)	(0.587)	(0.635)	(0.225)	(0.469)	(0.203)	(0.465)
Constant	−0.788	−0.611	−0.019	0.117	0.231	0.068	0.068
	(0.489)	(0.389)	(0.323)	(0.096)	(0.215)	(0.111)	(0.234)
Trading days	245	245	245	245	245	245	240
Trading days with ann.	59	59	59	59	59	59	57

	Panel b): Agricultural commodities						
	Cocoa	Coffee	Corn	Cotton	Soybeans	Soybean Oil	Wheat
Announcement	0.584**	0.713**	0.389**	0.537**	0.243*	0.523**	0.215
	(0.260)	(0.339)	(0.189)	(0.237)	(0.150)	(0.219)	(0.261)
Constant	−0.174	−0.112	−0.012	−0.077	0.069	−0.002	−0.001
	(0.125)	(0.175)	(0.104)	(0.104)	(0.074)	(0.107)	(0.114)
Trading days	240	240	240	240	240	240	240
Trading days with ann.	58	58	57	57	57	57	57

This table shows the results of estimating equation (1) that regresses the daily log return, R_t, on a constant and an indicator variable that takes on the value of one if there is a vaccine announcement on that day and zero otherwise. We include one lag in corn and soybeans, two lags of return in lumber, and four lags in the crude oil based on the Schwarz information criterion. The lag coefficient estimates are not reported for conciseness but are available upon request. The log return is computed as $R_t = \ln(P_t/P_{t-1}) \cdot 100$ where P_t is the closing price on day t. The estimation uses the set of vaccine announcements selected as described in Section 4.1. The number of trading days varies across markets because of opening hours and holidays observed in these markets. The OLS regression is used. The sample period is from January 22, 2020 to December 31, 2020. White (1980) standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.