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

Online Appendix[*]

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1 List of Vaccine Announcements

This section shows the list of vaccine announcements released by the four leading vaccine developers analyzed in our paper. Table A1 presents the list. There are 21, 58, 25, and 36 announcements for the Johnson & Johnson, Moderna, Oxford-AstraZeneca, and P zer-BioNTech vaccines, respectively, resulting in 140 announcements. The rst vaccine announcement is on January 23, 2020 and the last one is on December 31, 2020. Section 3.1 in the paper provides details about the methodology used for collecting this data.

Table A1: List of Vaccine Announcements

No.	Vaccine	Date	Time	Announcement	Day	Selected
1	Moderna	01/23/20	09:15	Moderna Announces Funding Award from CEPI (Coalition for Epidemic Preparedness Innovations) to Accelerate Development of Messenger RNA (mRNA) Vaccine Against Novel Coronavirus	1	Yes (1)
2	J&J	01/29/20	08:48	Johnson & Johnson Launches Multi-Pronged Response to Coronavirus Global Public Health Threat	2	No

17	Moderna	04/16/20	17:55	Moderna Announces Award from U.S. Government Agency BARDA (the Biomedical Advanced Research and Development Authority) for up to $483 Million to Accelerate Development of mRNA Vaccine (mRNA-1273) Against Novel Coronavirus	13	Yes (1)
18	Oxford-AstraZeneca	04/17/20	13:07	Five Oxford COVID-19 Projects Receive UK Research and Innovation (UKRI) Funding	13	Yes (1)

33 Oxford-AstraZeneca 06/04/20 11:00 AstraZeneca Takes Next Steps towards Broad and Equitable Access to Oxford University's

49	Moderna	07/26/20	10:22	Moderna Announces Expansion of BARDA Agreement to Support Larger Phase 3 Program for Vaccine (mRNA-1273) Against COVID-19	41	Yes (1)
50	Moderna	07/27/20	06:52	Moderna Announces Phase 3 COVE (Coronavirus E cacy) Study of mRNA Vaccine Against COVID-19 (mRNA-1273) Begins	41	Yes (2)
51	P zer-BioNTech	07/27/20	17:15	P zer and BioNTech Choose Lead mRNA Vaccine Candidate Against COVID-19 and Commence Pivotal Phase 2/3 Global Study	42	Yes (2)
52	Moderna	07/28/20	15:23	Moderna Announces Publication in The New England Journal of Medicine of Non-Human Primate Preclinical Viral Challenge Study of its mRNA Vaccine Against COVID-19 (mRNA-1273)	42	No
53	J&J	07/30/20	05:30	Single Dose of Johnson & Johnson COVID-19 Vaccine Candidate Demonstrates Robust Protection in Pre-clinical Studies	43	Yes (2)
54	P zer-BioNTech	07/31/20	05:15	P zer and BioNTech to Supply Japan with 120 Million Doses of their BNT162 mRNA-based Vaccine Candidate	44	No
55	P zer-BioNTech	08/05/20	08:00	P zer and BioNtech to Supply Canada with their BNT162 mRNA-Based Vaccine Candidate	45	No
56	J&J	08/05/20	08:30	Johnson & Johnson Announces Agreement with U.S. Government for 100 Million Doses of Investigational COVID-19 Vaccine	45	Yes (4)
57	Moderna	08/11/20	17:49	Moderna Announces Supply Agreement with U.S. Government for Initial 100 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	46	Yes (4)
58	Oxford-AstraZeneca	08/14/20	07:13	AstraZeneca Concludes Agreement with the European Commission for the Supply of up to 400 Million Doses of AZD1222 COVID-19 Vaccine	47	No
59	J&J	08/14/20	09:58	Johnson & Johnson Announces Collaboration in Principle with the United Kingdom on Additional Phase 3 Study and Agreement to Supply its COVID-19 Vaccine Candidate	47	No
60	P zer-BioNTech	08/20/20	20:00	P zer and BioNTech Share Positive Early Data on Lead mRNA Vaccine Candidate BNT162b2 Against COVID-19	48	No
61	Moderna	08/24/20	09:18	Moderna Con rms Advanced Discussions with European Commission to Supply Europe with 80 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	49	Yes (4)
62	Moderna	08/26/20	08:53	Moderna to Present New Interim Clinical Data About mRNA Vaccine Against COVID-19 (mRNA-1273) at Advisory Committee on Immunization Practices (ACIP) Meeting	50	No
63	Moderna	08/28/20	06:19	Moderna Con rms Discussions with the Ministry of Health, Labour and Welfare to Supply Japan with 40 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	51	No

64	J&J	08/31/20	08:55	Johnson & Johnson Announces Agreement in Principle with Government of Canada to Supply its COVID-19 Vaccine Candidate	52	No
65	Oxford-AstraZeneca	08/31/20	16:30	Development of COVID-19 Vaccine AZD1222 Expands into US Phase III Clinical Trial Across All Adult Age Groups	53	Yes (2)
66	Oxford-AstraZeneca	08/31/20	16:30	AstraZeneca's Scienti c and Social Commitment for COVID-19 Vaccine	53	No
67	J&J	09/08/20	06:30	Biopharma Leaders Unite to Stand with Science	54	No
68	Moderna	09/08/20	06:30	Biopharma Leaders Unite to Stand with Science	54	No
69	Oxford-AstraZeneca	09/08/20	10:00	Biopharma Leaders Unite to Stand with Science	54	No
70	P zer-BioNTech	09/08/20	10:00	Biopharma Leaders Unite to Stand with Science	54	No
71	P zer-BioNTech	09/09/20	06:15	P zer and BioNTech to Potentially Supply the EU with 200 Million Doses of mRNA-based Vaccine Candidate Against SARS-CoV-2	55	Yes (4)
72	Oxford-AstraZeneca	09/09/20	09:00	Statement on AstraZeneca Oxford SARS-CoV-2 Vaccine, AZD1222, COVID-19 Vaccine Trials Temporary Pause	55	No
73	Oxford-AstraZeneca	09/12/20	09:20	COVID-19 Vaccine AZD1222 Clinical Trials Resumed in the UK	56	Yes (2)
74	P zer-BioNTech	09/12/20	10:45	P zer and BioNTech Propose Expansion of Pivotal COVID-19 Vaccine Trial	56	Yes (2)
75	P zer-BioNTech	09/15/20	13:45	P zer Investor Day Features Signi cant Number of Pipeline Advances for COVID-19 Programs and Across Numerous Therapeutic Areas	57	No
76	Moderna	09/22/20	12:22	Canada Exercises Increased Option for 20 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	58	No
77	J&J	09/23/20	06:45	Johnson & Johnson Announces Initiation of Pivotal Global Phase 3 Clinical Trial of Janssen's COVID-19 Vaccine Candidate	59	Yes (2)
78	J&J	09/25/20	15:09	Johnson & Johnson Posts Interim Results from Phase 1/2a Clinical Trial of its Janssen COVID-19 Vaccine Candidate (This statement was updated on October 4, 2020 to include additional information)	60	Yes (2)
79	J&J	09/28/20	17:45	Johnson & Johnson's One Dose COVID-19 Vaccine Trial with 60,000 Volunteers in Final Testing Phase	61	No
80	Moderna	09/29/20	18:17	Moderna Announces Publication in The New England Journal of Medicine of Interim Results From Older Adult Age Cohorts in Phase 1 Study of its mRNA Vaccine Against COVID-19 (mRNA-1273)	62	Yes (2)

81	Oxford-AstraZeneca	10/02/20	03:30	COVID-19 Vaccine AZD1222 Clinical Trial Resumed in Japan, Follows Restart of Trials in the UK, Brazil, South Africa and India	63	No
82	J&J	10/04/20	N/A	Update on Interim Results from Phase 1/2a Clinical Trial of its Janssen COVID-19 Vaccine Candidate	64	Yes (2)
83	P zer-BioNTech	10/06/20	07:00	BioNTech and P zer Initiate Rolling Submission to European Medicines Agency for SARS-CoV-2 Vaccine Candidate BNT162b2	65	No
84	Moderna	10/08/20	06:50	DARPA (The Defense Advanced Research Projects Agency) Awards Moderna up to $56 Million to Enable Small-Scale, Rapid Mobile Manufacturing of Nucleic Acid Vaccines and Therapeutics	66	Yes (1)
85	J&J	10/08/20	07:50	Johnson & Johnson Announces European Commission Approval of Agreement to Supply 200 Million Doses of Janssen's COVID-19 Vaccine Candidate	66	Yes (4)
86	J&J	10/12/20	21:16	Johnson & Johnson Temporarily Pauses All Dosing in Our Janssen COVID-19 Vaccine Candidate Clinical Trials	67	No

96	P zer-BioNTech	11/11/20	06:15	P zer and BioNTech Reach an Agreement to Supply the EU with 200 Million Doses of Their BNT162b2 mRNA-Based Vaccine Candidate Against SARS-CoV-2	75	Yes (4)
97	Moderna	11/11/20	16:01	Moderna Has Completed Case Accrual for First Planned Interim Analysis of its mRNA Vaccine Against COVID-19 (mRNA-1273)	76	No
98	Moderna	11/13/20	07:18	Swissmedic Begins Rolling Review of Moderna's mRNA Vaccine Against COVID-19 (mRNA-1273)	77	No
99	J&J	11/14/20	09:34	Johnson & Johnson and U.S. Department of Health & Human Services Expand Agreement to Support Next Phase of COVID-19 Vaccine Candidate Research and Development	78	Yes (1)
100	J&J	11/15/20	N/A	Johnson & Johnson Initiates Second Global Phase 3 Clinical Trial of its Janssen COVID-19 Vaccine Candidate	78	Yes (2)
101	Moderna	11/16/20	06:52	Moderna Announces Longer Shelf Life for its COVID-19 Vaccine Candidate at Refrigerated Temperatures	78	No
102	Moderna	11/16/20	06:56	Moderna's COVID-19 Vaccine Candidate Meets its Primary E cacy Endpoint in the First Interim Analysis of the Phase 3 COVE Study	78	Yes (2)
103	P zer-BioNTech	11/16/20	08:00	P zer Update on Our U.S. COVID-19 Vaccine Candidate Distribution Preparedness	78	No
104	Moderna	11/17/20	09:11	Moderna Announces Supply Agreement with United Kingdom Government to Supply mRNA Vaccine Against COVID-19 (mRNA-1273) if Approved for Use	79	No
105	Moderna	11/17/20	09:18	European Medicines Agency Begins Rolling Review of Moderna's mRNA Vaccine Candidate Against COVID-19 (mRNA-1273)	79	No
106	P zer-BioNTech	11/18/20	06:59	P zer and BioNTech Conclude Phase 3 Study of COVID-19 Vaccine Candidate, Meeting All Primary E cacy Endpoints	80	Yes (2)
107	Oxford-AstraZeneca	11/19/20	12:08	Oxford Coronavirus Vaccine Produces Strong Immune Response in Older Adults	81	Yes (2)
108	P zer-BioNTech	11/20/20	06:45	P zer and BioNTech to Submit Emergency Use Authorization Request Today to the U.S. FDA for COVID-19 Vaccine	82	No
109	Oxford-AstraZeneca	11/23/20	02:00	AZD1222 Vaccine Met Primary E cacy Endpoint in Preventing COVID-19	83	Yes (2)
110	Moderna	11/25/20	06:49	Moderna Announces the European Commission's Approval of Advance Purchase Agreement for Initial 80 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	84	Yes (4)
111	Moderna	11/29/20	08:37	Moderna Announces Amendment to Current Supply Agreement with United Kingdom Government for an Additional 2 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	85	No

112	Moderna	11/30/20	06:59	Moderna Announces Primary E cacy Analysis in Phase 3 COVE Study for Its COVID-19 Vaccine Candidate and Filing Today with U.S. FDA for Emergency Use Authorization	85	No
113	J&J	12/01/20	08:41	Johnson & Johnson Announces Initiation of Rolling Submission for its Single-dose Janssen COVID-19 Vaccine Candidate with the European Medicines Agency	86	No
114	P zer-BioNTech	12/02/20	02:05	P zer and BioNTech Achieve First Authorization in the World for a Vaccine to Combat COVID-19	87	Yes (5)
115	Moderna	12/03/20	05:07	Moderna Provides Updates on the Clinical Development and Production of Its COVID-19 Vaccine Candidate	88	No
116	Moderna	12/04/20	08:27	Moderna Announces Amendment to Supply Agreement with the Ministry of Health of Israel to Supply Additional Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	89	No
117	Moderna	12/07/20	09:27	Canada Exercises Increased Option for Total of 40 Million Doses of mRNA Vaccine Candidate Against COVID-19 (mRNA-1273)	90	No
118	Moderna	12/08/20	08:00	Switzerland Exercises Increased Option for 7.5 Million Doses of mRNA Vaccine Against COVID-19 (mRNA-1273)	91	No
119	Oxford-AstraZeneca	12/08/20	11:00	AZD1222 Oxford Phase III Trials Interim Analysis Results Published in The Lancet	91	Yes (2)
120	Moderna	12/10/20	07:00	Moderna Announces First Participants Dosed in Phase 2/3 Study of COVID-19 Vaccine Candidate in Adolescents	92	Yes (2)

128	Moderna	12/17/20	17:27	Moderna Receives FDA Advisory Committee Vote Supporting Emergency Use for Moderna's Vaccine Against COVID-19 in the United States	97	No
129	Moderna	12/18/20	08:00	European Commission Exercises Option for Additional 80 Million Doses of Moderna's COVID-19 Vaccine Candidate	97	Yes (4)
130	Moderna	12/18/20	19:46	Moderna Announces FDA Authorization of Moderna COVID-19 Vaccine in U.S.	98	Yes (5)
131	Moderna	12/19/20	21:44	U.S. CDC (Centers for Disease Control and Prevention) Advisory Committee on Immunization Practices Recommends Vaccination with Moderna's COVID-19 Vaccine for Persons 18 Years and Older	98	No
132	P zer-BioNTech	12/21/20	09:21	P zer and BioNTech Receive CHMP (the Committee for Medicinal Products for Human Use) Positive Opinion for their COVID-19 Vaccine	98	No

2 Impact of Vaccine Announcements on Days Preceding and Following the Announcements

This section tests for any potential impact that the vaccine announcements might have in the days preceding or following the announcements. We estimate the following equation (1):

$$R_t = \beta_0 + \sum_{l=1}^{k} \beta_l R_{t-l} + \sum_{k=-3}^{3} \gamma_k Ann_{t+k} + \varepsilon_t; \quad (1)$$

Table A2: Test for Pre-announcement and Post-announcement E ects

	OLS Regression
Lead 3	0.135 (0.331)
Lead 2	0.268 (0.272)
Lead 1	0.455 (0.325)
Announcement	0.850 (0.239)***
Lag 1	0.069 (0.253)
Lag 2	0.238 (0.324)
Lag 3	0.231 (0.262)
Constant	0.074 (0.213)

This table shows the results of estimating equation (1) that regresses the daily log return, R_t, on a constant, seven lags of return as well as three leads, the contemporaneous value and three lags of the indicator variable that takes on the value of one if there is an important vaccine announcement on that day and zero otherwise. The log return is computed as R_t

return lags, L, is determined with the Schwarz information criterion and results in zero lags for BioNTech and Moderna and one lag for the other three companies. Ann_t is an indicator variable that takes on the value of one if there is a vaccine announcement about this company on that day and zero otherwise. Since our sample includes only positive news about the vaccine development as described in Section 3 of the paper, a positive coe cient on the announcement indicator variable, , means that the good news increases the return.

Table A3 reports the results. For conciseness, the coe cients on the return lags are not reported and are available upon request. The coe cient on the announcement indicator variable is signi cant for all four companies involved in development of the vaccines that have been approved in the U.S. (BioNTech, Johnson & Johnson, Moderna, and P zer). This means that the company stock returns are higher on days when these companies release the vaccine announcements. The Moderna and BioNTech stock prices on average move by 3.2% and 4.8%, respectively, on the vaccine announcement days. This impact is large probably because the COVID-19 vaccine is a substantial part of business in these corporations. The magnitude of the Johnson & Johnson and P zer stock price moves is lower (1.1% and 1.6%, respectively), perhaps because they are larger corporations diversi ed into other products.

The coe cient is not signi cant for AstraZeneca. Although the AstraZeneca vaccine was approved in the EU and other regions, the vaccine was lagging behind the Johnson & Johnson, Moderna, and P zer-BioNTech vaccines in the U.S. approval process. Also, on June 4, 2020 AstraZeneca released announcement #33 in Table A1 in which Pascal Soriot, AstraZeneca Chief Executive O cer, announced: *We are working tirelessly to honour our commitment to ensure broad and equitable access to Oxford's vaccine across the globe and at no pro t. Today marks an important step in helping us supply hundreds of millions of people around the world, including to those in countries with the lowest means..."* Perhaps investors considered this pricing decision and predicted the U.S. approval challenges and therefore did not react to the vaccine announcements as enthusiastically.

To gain a perspective on the economic signi cance of the Table A3 results, we compute

Table A3: Impact of Vaccine Announcements on Leading Vaccine Company Stocks

	AstraZeneca	BioNTech	J & J	Moderna	P zer	Random E ects
Announcement	0:288	4:805**	1:107**	3:247***	1:620***	2:580***
	(0:372)	(2:046)	(0:473)	(1:079)	(0:506)	(0:475)
Constant	0:017	0:306	0:048	0:007	0:236	0:168
	(0:157)	(0:496)	(0:129)	(0:437)	(0:147)	(0:241)
Other company ann.						0:116
						(0:357)
Trading days	240	240	240	240	240	240
Trading days with ann.	19	32	19	50	32	99

This table shows the results of estimating equation (2) 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 about the given company on that day and zero otherwise. We include one lag in the AstraZeneca, Johnson & Johnson (J & J), and P zer equations; for conciseness, the coe cients on the return lags are not reported and are available upon request. The return is computed as $R_t = \ln(P_t=P_{t\ 1})\ \ 100$ where P_t is the closing stock price of the given company on day t. The sample period is from January 22, 2020 to December 31, 2020. Heteroskedasticity consistent standard errors are shown in parentheses. *, **, and *** indicate statistical signi cance at 10%, 5%, and 1% levels, respectively.

cumulative stock returns by multiplying the coe cient estimate on the announcement indicator for each vaccine company by their announcement days. Moderna, BioNTech, P zer, and Johnson & Johnson earned approximately 162%, 154%, 52%, and 21% on their announcement days, respectively, and these returns accounted for a majority of total returns earned by these companies even though most trading days did not have announcements.

Equation (2) includes only announcements of the given company. To allow for the possibility that the company returns are also a ected by announcements made by the other four companies, we control for the other company announcements.

We use the random e ects panel estimator:

$$R_{it} = \ _0 + \sum_{l=1}^{k} \ _l R_{it-l} + \ Ann_{it} + \ AnnOther_{it} + \ _t + \ _{it}; \qquad (3)$$

where Ann_{it} is an indicator variable that takes on the value of one if there is a vaccine announcement about company *i* on that day and zero otherwise, $AnnOther_{it}$ is an indicator variable that takes on the value of one if there is an announcement about any of the other

We estimate the daily cash ow news and the discount rate news for the S&P 500 index using the return decomposition approach proposed by Campbell and Shiller (1988). Campbell and Shiller (1988) derive the following accounting identity that decomposes the unexpected stock returns into news about future dividends and future discount rates:

$$r_{t+1} \quad E_t r_{t+1} = (E_{t+1} \quad E_t) \sum_{j=0}^{1} {}^{j} d_{t+1+j} \quad (E_{t+1} \quad E_t) \sum_{j=1}^{1} {}^{j} r_{t+1+j} = N_{CF;t+1} \quad N_{DR;t+1}; \quad (4)$$

where r_{t+1} is a log stock return, E_t and E_{t+1} are expectations at time t and $t + 1$, d_{t+1} is a one-period change in the log dividends, is a constant discount factor, $N_{CF;t+1}$ is news about future cash ows, and $N_{DR;t+1}$ is news about future discount rates. To construct the time series of the aggregate cash ow news and the aggregate discount rate news, we follow Campbell and Vuolteenaho (2004) and estimate the rst-order vector autoregression (VAR):

$$z_{t+1} = a + Bz_t + u_{t+1}; \quad (5)$$

where z_{t+1} is a vector of state variables, a and B are coe cient matrices, and u_{t+1} is a vector of shocks. The excess stock market return is the rst state variable in the VAR, and the other state variables are selected to model the time variation in expected returns. The discount rate news can then be computed as:

$$N_{DR;t+1} = e1^{0} \; u_{t+1}; \quad (6)$$

where $e1$ is a vector with the rst element equal to one and the other elements equal to zero, and $B(I \quad B)^{-1}$ is a matrix that captures the long-term e ects of VAR innovations on the state variables. We set the daily discount factor equal to 0.9998 (0.95 annualized following Campbell and Vuolteenaho (2004)). Campbell (1993) shows that is related to the average consumption-wealth ratio. Speci cally, $= 1 \quad exp(c \quad w)$, where c and w are the natural logs of consumption and total wealth, respectively; therefore, setting equal to 0.95 assumes that investors consume about 5% of their wealth per year on average. We then calculate the cash ow news using the market return shock and the discount rate news:

$$N_{CF;t+1} = (e1^{0} + e1^{0})u_{t+1}: \quad (7)$$

This calculation treats the cash ow news as a residual. In principle, it is possible to model the cash ow news directly. For example, Chen and Zhao (2009) do this by constructing cash ow proxies from annual nancial statements data. However, this approach cannot be used to construct a daily time series of the aggregate cash ow news.

Following Atilgan, Bali, and Demirtas (2015), we use a return decomposition based on a daily VAR that includes the log excess return of the S&P 500 index, the dividend yield of the S&P 500 index, the relative Treasury bill rate (the di erence between the three-month Treasury bill rate and its moving average over the last 12 months), the credit spread (the di erence between the Moody's BAA and AAA bond yields), and the term spread (the di erence between the 10-year and three-month constant maturity Treasury yields). The dividend yield of the S&P 500 index is obtained from the OptionMetrics database. All interest rates are obtained from the FRED database. The dividend yield, the relative Treasury bill rate, the credit spread, and the term spread are commonly used predictors of equity market returns (Campbell, 1991; Campbell & Vuolteenaho, 2004; Bernanke & Kuttner, 2005; Fama & French, 1989), and Atilgan et al. (2015) use the same predictors in their return decomposition. To simplify the interpretation of the VAR coe cient estimates, we standardize all VAR variables except the market excess return to a mean of zero and standard deviation of one.

We estimate the VAR using daily data from January 2017 to December 2020. The coe cient estimates are shown in Table A4. All predictor variables except the relative Treasury bill rate are statistically signi cant in the market excess return equation. The dividend yield positively predicts excess stock returns. The credit spread and the term spread are also signi cant predictors of next-day returns. There is also some evidence of next-day reversal in the market return. The R^2 of the return equation is approximately 9.3%.

We conduct several robustness checks. The results for the cash ow and discount rate news are similar if we shorten the period used in computing the moving average for the

Table A4: Vector Autoregression (VAR) Parameter Estimates

	Constant	$r^e_{m;t}$	DY_t	RTB_t	TS_t	CS_t	R^2
$r^e_{m;t+1}$	0:057	0:267***	0:190***	0:048	0:166***	0:378***	0:093
	(0:040)	(0:086)	(0:103)	(0:072)	(0:060)	(0:127)	
DY_{t+1}	0:002	0:020**	1:002***	0:009**	0:004	0:014*	0:995
	(0:002)	(0:009)	(0:005)	(0:004)	(0:004)	(0:008)	
RTB_{t+1}	0:001	0:0002	0:004	0:999***	0:010***	0:009**	0:998
	(0:001)	(0:002)	(0:003)	(0:002)	(0:002)	(0:004)	
TS_{t+1}	0:002	0:011	0:018	0:003	0:972***	0:021**	0:971
	(0:005)	(0:007)	(0:011)	(0:005)	(0:007)	(0:010)	
CS_{t+1}	0:001	0:005	0:108**	0:029*	0:068***	0:827***	0:910
	(0:010)	(0:022)	(0:041)	(0:016)	(0:016)	(0:044)	

This table shows the OLS parameter estimates for the first-order VAR including a constant, the log excess return of the S&P 500 index ($r^e_{m;t}$), the dividend yield of the S&P 500 index (DY_t), the relative Treasury bill rate (RTB_t), the term spread (TS_t), and the credit spread (CS_t). All variables are measured at daily intervals. All variables except the market excess return are standardized to a mean of zero and standard deviation of one. The sample period is from January 2017 through December 2020 and contains 1,006 daily observations. Heteroskedasticity consistent standard errors are in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

relative Treasury bill rate, replace the relative Treasury bill rate with a simple daily change in the Treasury bill rate or shorten the sample period used to estimate the VAR to 2018-2020. The results are also similar if we remove the remaining autocorrelation at higher lags from the estimated cash flow news and discount rate news using an autoregressive model.

Table A5 shows correlations of the VAR residuals and their correlations with the estimated cash flow shocks and discount rate shocks in our sample period from January 22, 2020 to December 31, 2020. The unexpected market returns are strongly negatively correlated with the credit spread innovations. In periods of market stress, stock prices decline and credit conditions tighten simultaneously. The correlations of return innovations with cash flow shocks and discount rate shocks are 0.80 and -0.68, respectively. News of higher expected cash flows and lower expected returns leads to higher current stock returns. There is some negative correlation between the cash flow shocks and discount rate shocks. This is consistent with a declining equity risk premium in good economic times when the expectations of corporate cash flows increase (for example, Campbell and Cochrane (1999)).

We then estimate OLS regressions of the cash flow news and discount rate news on the

Table A5: Correlations of Cash Flow News, Discount Rate News, and VAR Residuals

	r_m^e shock	DY shock	RTB shock	TS shock	CS shock	N_{CF}
DY shock	0:013					
RTB shock	0:211***	0:352***				
TS shock	0:326***	0:334***	0:301***			
CS shock	0:225***	0:211***	0:063	0:126*		
N_{CF}	0:804***	0:054	0:139**	0:228***	0:239***	
N_{DR}	0:678***	0:045	0:525***	0:263***	0:671***	0:107*

The table shows Pearson correlations of residuals from the VAR with the estimated cash ow news and discount rate news. The sample period is from January 22, 2020 through December 31, 2020 and contains 240 daily observations. *, **, *** indicate that the correlation is statistically signi cant at 10%, 5%, and 1% levels, respectively.

vaccine news indicator variable. The results are reported in Table 4 in the paper along with the related discussion.

5 Impact of Vaccine Announcements on Developed and Emerging Stock Markets

This section tests whether the impact of vaccine announcements di ers between developed and emerging markets. We estimate the following panel regression:

$$R_{i;t} = {}_0 + {}_1 R_{i;t-1} + EM_i + {}_1 Ann_t + {}_2 Ann_t \quad EM_i + {}_i + {}_{i;t}; \tag{8}$$

where $R_{i;t}$ is de ned as the log return for the given market i on day t, EM_i is an indicator variable equal to one for emerging markets and zero otherwise, and ${}_i$ stands for the market-speci c random e ects (i.e., cross-section random e ects). We use the MSCI Classi cation of markets from https://www.msci.com/market-classification/ . Australia, Canada, Hong Kong, Japan, South Korea, the U.S. and the European countries are classi ed as developed markets while China, India, Mexico, Nigeria, and South Africa are classi ed as emerging markets. We include returns for the 19 stock indices analyzed in the paper (the U.S. stock

market analyzed in Table 2 and 18 other stock markets analyzed in Table 5). Table A6 reports the results. The coe cient $_2$ is not statistically signi cant. Therefore, developed and emerging markets do not di er in their reaction to vaccine announcements.

Table A6: Test for a Di erence in the Impact of Vaccine Announcements on Developed and Emerging Stock Markets

Announcement	0.602 (0.223)***
Announcement*EM	0.085 (0.143)
EM	0.097 (0.067)
Constant	0.161 (0.120)
Number of time periods (Trading days)	249
Number of cross-sections (Markets)	19
Total panel observations	4,535

This table shows the results of estimating equation (8) that regresses the log return, $R_{i;t}$ for market i on day t, on a constant, one lag of the return, a dummy variable EM_i equal to one for emerging markets and zero otherwise, an indicator variable that takes on the value of one if there is a vaccine announcement on that day and zero otherwise, and an interaction term multiplying this vaccine announcement variable by EM_i. The estimation uses a set of vaccine announcements selected as described in Section 4.1. The random e ects panel estimator is used. The sample period is from March 23, 2020 to December 31, 2020. Standard errors corrected for correlations across markets are shown in parentheses. *, **, and *** indicate statistical signi cance at 10%, 5%, and 1% levels, respectively.

6 Robustness Checks

This section provides supplementary material for robustness checks mentioned in Section

announcements about vaccines not approved in EU, the U.K., or the U.S. but approved in another country. The two such vaccines with the largest market are the Sinopharm-BIBP and Sinovac vaccines developed in China. We collect announcements about these two vaccines from the Sinopharm and Sinovac websites as well as multiple Chinese online media

imprisoned for leaking macroeconomic data. Some studies, such as Koch-Weser (2013), have

coe cient estimate of the average macroeconomic surprise is not statistically signi cant. Two possible reasons may account for this nding. First, according to the estimates of Kurov et al.

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