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The price of COVID-19-induced uncertainty in the options market☆

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ABSTRACT

This paper investigates the pricing of uncertainty associated with the COVID-19 responses for 28 countries/regions in 2020. We find that such uncertainty is priced in the equity options market. Specifically, there is a price premium for options that provide protection to hedge against price risk, variance risk, and tail risk caused by a variety of World Health Organization (WHO) announcements and the lockdown announcements from governments on COVID-19. Moreover, such options tend to be more expensive when the governments place stricter restrictions.

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1. Introduction

In this paper, we analyze options market reaction to uncertainty associated with the World Health Organization (WHO) announcements and government stringency policies on COVID-19 in the global context. Prior literature extensively examines the impact of the COVID-19 outbreak on performance and stability of global stock markets (see, e.g., Al-Awadhi et al., 2020; Ali et al., 2020; Ashraf, 2020; Baek et al., 2020; Baig et al., 2021; Haroon and Rizvi, 2020; Liu et al., 2020; Zhang et al., 2020). The novel coronavirus crisis has prompted a striking range of global responses to the deteriorating economic conditions. Disease outbreak news and government interventions lead to uncertainty that causes portfolio reconstructions and unique trading activity (Zaremba et al., 2020). To the best of our knowledge, the forward-looking evidence of such uncertainty for the global options markets is quite limited. Our study considers the WHO announcements and government policies as the COVID-19-induced uncertainty sources and uses three option market measures to quantify to what extent the options market acknowledges such uncertainty in the short term.

There are several studies measure the structural breaks in the evolution of stock market returns and stability caused by government responses and WHO announcements on COVID-19 (see, e.g., Agarwalla et al., 2021; Phan and Narayan, 2020; Schell et al., 2020; Scherf et al., 2021). Arteaga-Garavito et al. (2021), among others, construct a novel data set comprising thousands of medical and contagion announcements and news obtained from the Internet and document the market price of such news. However, only a handful of papers underline the impact of these responses on the options market (Hanke et al., 2020; Jackwerth, 2020; Li et al., 2021). We expand the geographic areas to 28 countries/regions and study uncertainty associated with six WHO announcements and the government announcements of the lockdown on COVID-19 in the options market.[1] Specifically, we first choose "bad news" out of all the WHO responses to COVID-19 for the reason that the impact of uncertainty caused by such events should presumably be reflected in the forward-looking measures.[2] We then use the at-the-money (ATM) IV, the variance

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[1] Among the 28 geographic areas, Hong Kong Special Administrative Region of China and Taiwan Province of China (abbreviated as Hong Kong and Taiwan hereafter) are categorized as regions, for they are defined as subdivisions of the People's Republic of China in the International Organization for Standardization (ISO) 3166 country codes (https://www.iso.org/iso-3166-country-codes.html). Morgan Stanley Capital International (MSCI) Inc. constructs country indices for each of the 28 countries/regions, allowing us to independently address the options market responses to COVID-19 in these areas. Therefore, for the sake of simplicity, country/region and countries/regions are replaced by country and countries in the rest of the paper.

[2] Onan et al. (2014) state that good and bad announcements asymmetrically impact the financial volatility. They find that bad surprises will increase the

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risk premium, and the IV slope, proposed by Kelly et al. (2016, KPV hereafter), to represent the price premia of option protection against such uncertainty; that is, the price risk, variance risk, and tail risk, during COVID-19, respectively. We also expand the study to the analyses of the effects of other global news and local news on the options market. Specifically, we consider how the U.S. lockdown and domestic lockdown announcements affect the price risk, variance risk, and tail risk of the global and local options market to refer to the effects of global news and local news, respectively. We find that the three variables of the options following the these COVID-19 announcement days tend to be more positive than those of the neighboring options on average. The differences are all statistically and economically significant, suggesting that there is a premium for the options that provide protection against uncertainty caused by the WHO and government responses.

We also examine the time-series effects of uncertainty associated with the government responses on the country level. There are some existing papers studying the country-level stock markets' reaction to specific government stringent policies (Bannigidadmath et al., 2021; Narayan et al., 2021; Xie et al., 2021). However, according to KPV, isolating exogenous variation in political uncertainty is the major issue when exploring its effect on the financial market, and it is even harder to distinguish such effect when the government introduces various and significant efforts to stop the market downturn, which is most likely triggered by the broader macro uncertainty. Therefore, as an extension of the previous event study of the local effects of domestic lockdown announcements, we resort to the stringency index from Oxford COVID-19 Government Response Tracker and conduct a time-series analysis. The stringency index is a composite measure based on nine response indicators (see, e.g., Bakry et al., 2021; Baig et al., 2021; Scherf et al., 2021; Zaremba et al., 2020, 2021). We test the relation between our three option measures and find it strongly positive, suggesting that the cost of option protection against uncertainty increases with stricter policy responses to COVID-19. We also examine the effect of the daily COVID-19 case/death news on uncertainty by regressing the option measures on the smoothed daily new confirmed cases and daily new death. The results show that the price of price risk and variance risk of COVID-19 is positively related to the daily new cases and deaths, which is consistent with the independent findings of Arteaga-Garavito et al. (2021), whereas the tail risk measure exhibits less sensitivity to news of the COVID-19 severity.

We provide convincing evidence that uncertainty associated with the official responses to COVID-19, that is, the WHO announcements and the country-specific restriction policies on COVID-19, is priced in the options market in the global context. The cost of option protection against such uncertainty increases following the WHO announcements and the government policies of containment for COVID-19. Our results are robust after controlling for the country-fixed effects and the government economic responses in each country.

The rest of the paper is organized as follows. Section 2 describes our data and specifies the variable construction. Our hypotheses are summarized in Section 3. Section 4 presents the major empirical results on the price premia of option protection against the risk associated with COVID-19-induced uncertainty, and Section 5 concludes.

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implied volatility (IV) slope, whereas good news do not seem to affect slope significantly. In this line, Albulescu (2021) shows that the stock return responses are also asymmetric in the increase and decrease in the confirmed cases in Canada during COVID-19. Xie et al. (2021) suggest there is a negative bias in terms of the magnitude of the stock markets' reaction to bad news, such as the COVID-19 lockdown announcements from governments, as compared to good news being the reopening announcements accordingly.

2. Data and methodology

2.1. Data

The daily data set for this study spans over January 2020 to December 2020 inclusive.[3] The OptionMetrics volatility surface database (provided by Wharton Research Data Services) provides the constant maturity, the matched delta, and the matched IV for standard option contracts. For 27 countries, we use data on U.S.-traded options on the iShares MSCI country-specific exchange traded funds (ETFs). For the U.S, we use the most traded and most widely used SPDR S&P 500 Trust ETF options. Table 1 reports the tickers of the ETFs, the names of the indices that these ETFs replicate, the inception dates, and the cumulative returns of the ETFs over the year 2020 for each country listed. The spot prices obtained from the Center for Research in Security Prices (CRSP) are for the computation of the historical volatility. We use the Treasury yield data and match the interest rate maturity to the option maturities by interpolation/extrapolation to proxy the risk-free rate.[4] Data of the WHO COVID-19 announcements are extracted from the WHO website.[5] We analyze the events that potentially deliver negative information concerning the severity of the COVID-19 coronavirus disease, that is, the "negative" announcements on COVID-19 from WHO and the government announcements of the lockdown.[6]

We also use the COVID-19 stringency index to conduct the country-level analysis.[7] Fig. 1 is a map of the stringency level on average for 28 countries during 2020. The containment strategies seem mild for most countries in terms of the year averages, but each country implements somewhat stricter controlling policies at certain stages in 2020.

2.2. Methodology

Following KPV, we use three option market variables to measure the reaction of option traders to the COVID-19 announcements and policies for each country. These variables, namely, *IV*, *VRP*, and *Slope*, capture the price risk, variance risk, and tail risk associated with such events, respectively.

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[3] The novel coronavirus was officially identified and reported since 2020. Our data ends on December 31, 2020 due to option data availability.

[4] The Treasury yield data are downloaded from the website of the United States Department of the Treasury. Retrieved from: https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield [Online Resource].

[5] Retrieved from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019 [Online Resource].

[6] We require that the time gap between any adjacent two announcements is no less than five weeks to avoid overlapping windows. We choose the most influential and informative negative shocks out of all the WHO responses: Declaration of a public health emergency of international concern (PHEIC) on January 30, 2020, characterization of the COVID-19 pandemic on March 11, 2020, issuance of a guidance on "lockdowns" on April 16, 2020, reporting a cluster of COVID-19 cases in Beijing, China, on June 13, 2020, issuance of the first survey on the impact of COVID-19 on health systems on August 13, 2020, and the World Health Summit starting on October 25, 2020.

[7] The stringency index (published online at OurWorldInData.org and retrieved from: https://ourworldindata.org/coronavirus-data) is designed to record the strictness of government policies and calculated as the mean score of nine metrics, including school closures, workplace closures, travel bans, etc. It is rescaled to a value from 0 to 100. A higher score indicates a stricter response to COVID-19.

[8] Policies vary at the subnational level in Brazil, Canada, the United Kingdom, and the United States. The index is shown as the average level across all the regions for those countries.

Table 1
Countries and indices.

Country	Ticker	Equity Index	Inception Date	CRET%
Australia	EWA	MSCI Australia Index	12-Mar-1996	2.32
Belgium	EWK	MSCI Belgium IMI 25/50 Index	12-Mar-1996	−1.01
Brazil	EWZ	MSCI Brazil 25/50 Index	10-Jul-2000	−22.65
Canada	EWC	MSCI Canada Custom Capped Index	12-Mar-1996	1.01
Chile	ECH	MSCI Chile IMI 25/50 Index	12-Nov-2007	−5.68
China	MCHI	MSCI China Index	29-Mar-2011	27.25
France	EWQ	MSCI France Index	12-Mar-1996	2.80
Germany	EWG	MSCI Germany Index	12-Mar-1996	7.71
Hong Kong	EWH	MSCI Hong Kong 25/50 Index	12-Mar-1996	1.23
India	INDA	MSCI India Index	02-Feb-2012	14.39
Indonesia	EIDO	MSCI Indonesia IMI 25/50 Index	05-May-2010	−11.43
Italy	EWI	MSCI Italy 25/50 Index	12-Mar-1996	0.18
Japan	EWJ	MSCI Japan Index	12-Mar-1996	13.93
Malaysia	EWM	MSCI Malaysia Index	12-Mar-1996	2.62
Mexico	EWW	MSCI Mexico IMI 25/50 Index	12-Mar-1996	−9.93
Netherlands	EWN	MSCI Netherlands IMI 25/50 Index	12-Mar-1996	24.42
New Zealand	ENZL	MSCI New Zealand IMI 25/50 Index	01-Sep-2010	16.63
Singapore	EWS	MSCI Singapore 25/50 Index	12-Mar-1996	−11.36
South Africa	EZA	MSCI South Africa 25/50 Index	03-Feb-2003	−8.28
South Korea	EWY	MSCI Korea 25/50 Index	09-May-2000	38.46
Spain	EWP	MSCI Spain 25/50 Index	12-Mar-1996	−5.43
Sweden	EWD	MSCI Sweden 25/50 Index	12-Mar-1996	22.03
Switzerland	EWL	MSCI Switzerland 25/50 Index	12-Mar-1996	7.98
Taiwan	EWT	MSCI Taiwan 25/50 Index	20-Jun-2000	32.29
Thailand	THD	MSCI Thailand IMI 25/50 Index	26-Mar-2008	−9.15
Turkey	TUR	MSCI Turkey IMI 25/50 Index	26-Mar-2008	−9.23
United Kingdom	EWU	MSCI United Kingdom Index	12-Mar-1996	−14.05

This table lists 28 countries and their major indices as of December 31, 2020. The tickers of the ETFs (Ticker), the inception dates of the indices (Inception Date) and their cumulative returns in percentage in 2020 (CRET%) are also reported.
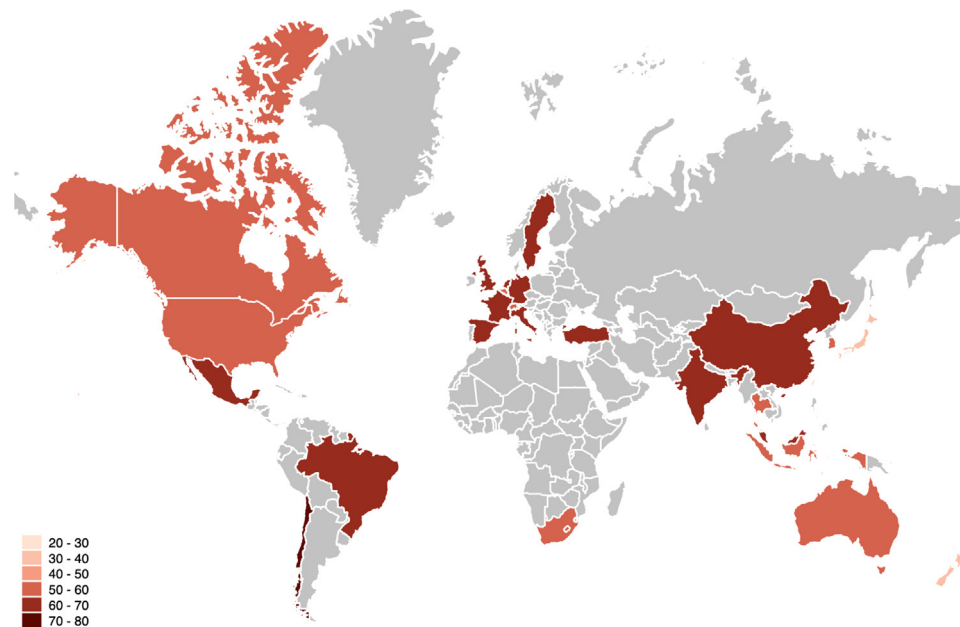

Fig. 1. Government response in 2020. This figure demonstrates the mean value of the COVID-19 stringency index in 2020 for each of the 28 countries obtained from OWID. The index records the strictness of government policies calculated as the mean score of nine metrics including school closures, workplace closures, travel bans, etc. It is rescaled to a value from 0 to 100 (100 = strictest).[8]

The first variable, *IV*, denotes the mean IV of the ATM options that satisfy $|\Delta| = 0.5$ with 30 days to expiration on a daily basis.[9] *IV* captures the cost of protection against price changes.

The second variable, the variance risk premium, is calculated as the difference between the implied and realized variances as

defined in Bollerslev et al. (2009). Following that approach, we construct the daily variance risk premium for each country:

$$VRP = IV^2 - RV^2, \tag{1}$$

where RV^2 is the realized variance calculated as the annualized variance of daily log returns of the index ETF over 30 days. *VRP* captures the cost of protection against general uncertainty-related volatility changes.

Our last main variable is the IV slope; that is, the steepness of the function that relates IVs to moneyness (measured using the

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[9] KPV define their ATM options as those whose deltas satisfy $0.4 < |\Delta| < 0.5$ out of concern that options that are slightly out-of-the-money (OTM) tend to be more liquid than options that are in-the-money (ITM). It is not an issue in our study since we use standardized option data, which is interpolated accurately using enough neighboring values and supposedly eliminates the concern in KPV.

option's Black–Scholes delta), given by

$$IV(\Delta) = \alpha + Slope \times \Delta + \epsilon_i. \qquad (2)$$

where $IV(\Delta)$ is the Black–Scholes IV of an OTM put option whose time to expiration is 30 days whose delta satisfies $-0.5 < \Delta < -0.1$. *Slope* denotes the coefficient estimate on deltas. Because deeper OTM puts are typically more expensive, *Slope* usually takes positive values. A more positive slope suggests a relatively higher cost of protection against downside tail risk.

We utilize the event study methodology to construct option variables to measure the global effects of WHO announcements of "bad news", the global effect of the U.S. lockdown, and the local effect of the domestic lockdown announcements, on uncertainty. For each announcement, we let X represent one of the option market measures, namely, *IV*, *VRP*, and *Slope*, and define the option variable difference for each country as

$$XD = \overline{X}_{\tau,0} - \frac{1}{2}(\overline{X}_{\tau,-2\tau} + \overline{X}_{\tau,2\tau}), \qquad (3)$$

where $\overline{X}_{\tau,0}$ is the mean value of the variable X during the prior τ days ending on the announcement day, i.e., day 0 (in the window $[-\tau+1,0]$, hereafter, the event window), and we skip τ days before and after the event window and calculate $\overline{X}_{\tau,-2\tau}$ and $\overline{X}_{\tau,2\tau}$ that are defined analogously as the average X during the prior τ days ending on the -2τth day and the 2τth day (in the pre- and post-announcement windows $[-3\tau+1, -2\tau]$ and $[\tau+1, 2\tau]$, hereafter, the neighboring window), respectively.[10] Similar to KPV, we require τ to be 30 days. However, due to the high frequency of the WHO announcements on COVID-19 during 2020, we set τ to be 7 days in the examination of WHO events.

XD is the values of the three option market variables following the event adjusted for the means calculated for the neighboring windows. A positive value of *XD* in Eq. (3) indicates that the options in the following days after the announcement are more expensive, on average, than those farther from the announcement.

3. Hypothesis

Fig. 2 reflects the evolution of daily cross-country averages of the three option market measures and the stringency index. We mark the days of the six WHO announcements with vertical dashed lines. The details of the WHO announcements and the lockdown announcements from governments are reported in Panel A and B of Table A.1, respectively. These announcements and the stringency index represent the official responses to COVID-19 from around the globe and each country. The three option market measures, namely, *IV*, *VRP*, and *Slope*, quantify the value of option protection against three aspects of risk: the price risk, variance risk, and tail risk associated with such responses, respectively.

First, most of the WHO announcements and the lockdowns seem to be closely followed by some upticks or large spikes in the time series of *IV*, *VRP*, and *Slope* in Fig. 2. Therefore, we formulate the following hypothesis:

Hypothesis 1. Option protection against uncertainty increases following the WHO announcements and the lockdown announcements from governments.

Second, due to the relatively infrequent policy measure changes, the time series of the mean stringency index is smoother than the three option market variables. However, we can still observe the variations of the index marked by the spikes of the main variables in Fig. 2. This leads to our next hypothesis:

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[10] If the announcement day falls on a weekend, day 0 is the first business day following this event.

Table 2
Descriptive statistics.

Panel A: Statistics							
	Mean	Std. Dev	Skew	Kurt	Min	Median	Max
RET	0.05	1.10	0.03	4.04	−2.36	0.04	2.52
IV	32.03	11.73	1.99	8.50	19.62	29.48	75.22
VRP	−1.88	16.11	2.35	12.56	−26.20	−3.80	56.31
Slope	70.71	59.95	1.36	5.62	−9.53	51.37	248.01

Panel B: Correlations			
	IV	VRP	Slope
RET	−0.04	−0.02	0.01
IV		0.71	0.03
VRP			0.06

This table reports the time-series averages of the cross-country statistics for the daily underlying equity returns (RET) and the three option market measures in 2020. *IV* is defined as the 30-day ATM IV, *VRP* is the variance risk premium, and *Slope* is computed as the IV slope of the 30-day OTM put options (with moneyness being measured by the option's delta, ranging between −0.5 and −0.1). The time-series averages of correlations in pairs are also reported. RET and the three option market measures are given in percentage terms.

Hypothesis 2. There is a positive relation between the strictness of the government responses to COVID-19 and the cost of option protection against uncertainty associated with such policies.

4. Results

4.1. Descriptive statistics

Table 2 reports the time-series averages of statistical properties of the three option market measures in the cross-country level and their Pearson correlations. In Panel A, the mean value of *IV* and *Slope* are positive at 32.03% and 70.71%, which is supportive of theory that protection against uncertainty, that is, price risk and tail risk, is costly. However, the mean *VRP* is negative at −1.88%, taken together with the minimum value of *VRP* (−26.20%), suggesting a volatile subsequent market condition which makes owning protection against uncertainty profitable. It is unlikely that the counter-parties would sell such options simply for the limited up-front payment but ignore risk of a market crash during the COVID-19 outbreak. We conjecture that, as COVID-19 rattles the global stock market, financial institutions may fail to take on enough short variance position because they are either cash-strapped or restricted to short sale constraints, which always exists in the context of extreme economic and financial turmoils, resulting in rare *VRP* values. Moreover, the variables are right-skewed with positive skewness values, and heavy-tailed with positive excess kurtosis values, indicating that they have more positive outliers than negative ones in 2020, as predicted by theory. In Panel B, we find that *IV* and *VRP* are positively correlated. KPV suggests that they are different conceptually and both informative because *IV* captures the price risk and *VRP* relates to the risk of the state price density changing.

4.2. Uncertainty around the WHO announcements and the lockdown announcements from government

In Fig. 2, it is visible that the option measures experience largest upward spikes in early 2020 around the first two WHO announcements, that is, declarations of COVID-19 to be a PHEIC and a pandemic. Based on this observation, we first apply an event study to investigate the statistical pattern of the reaction of *IV*, *VRP*, and *Slope* to the six WHO announcements specified in Panel A of Table A.1. Specifically, we estimate the mean value of *IVD*, *VRPD*, and *SlopeD* in Eq. (3) for the six events using the one-sided ordinary least squares (OLS) test clustering the standard
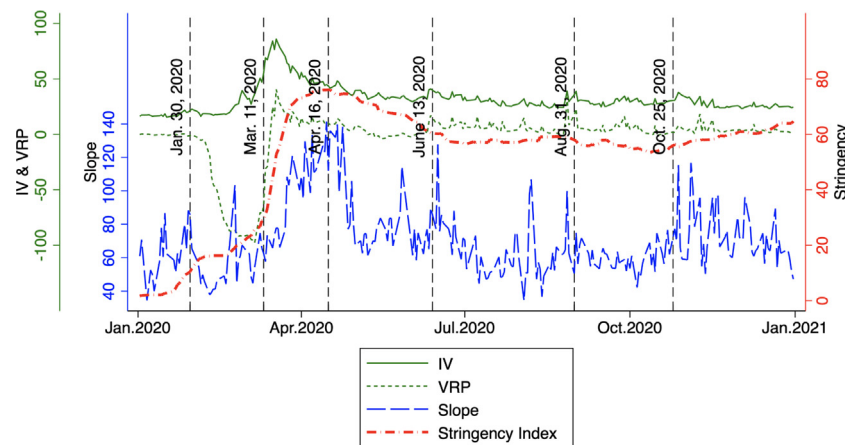
Fig. 2. Evolution of variables. This figure demonstrates the time series of the mean focal variables of the 28 index ETF options listed in Table 1 in this paper and the mean stringency index of the corresponding 28 countries in 2020, that is, *IV*, *VRP*, *Slope*, and Stringency, respectively. The three option measures are given in percentage terms. The vertical dashed lines denote the six WHO events identified in Section 2.1.

errors by country.[11] The *p*-values of the mean option measures are reported in Panel A of Table 3. The highly significant mean values support our hypothesis that uncertainty caused by the COVID-19-related WHO announcements is priced in the options market, consistent with the observations in Fig. 2.

Next, we study the global effect of the U.S. lockdown announcement and the local effects of the domestic lockdown announcements. The event dates are specified in Panel B of Table A.1.[12] We report the mean values of *IVD*, *VRPD*, and *SlopeD* over 30-day windows of the one-sided OLS test in Panel B and C of Table 3. We then pool all the countries and all the announcements and report the variables in Panel D. The evidence reported in Table 3 is consistent and suggests that uncertainty caused by the COVID-19-related WHO announcements, the U.S. lockdown, and the domestic lockdown announcements is priced in the options market in the global context.[13]

We also assess the economic value of the option protection and give examples using the values in Panel A of Table 3, that is, the relative expensiveness of the options that provide protection against COVID-19-induced uncertainty around the WHO announcements. The mean *IVD* is 7.96% per year, which implies that the 30-day ATM put options following a WHO announcement are 24.8% more expensive than their neighboring options on average.[14] 24.8% is an incredibly large price premium, which means that investors are willing to pay 24.8% more at purchasing insurance against the price risk embedded in the COVID-19-related WHO events.[15] Second, the mean *VRPD* is also large (11.28%) in our international sample during the WHO announcements in 2020, with the average *VRP*s in the event window and the neighboring window being 2.89% and −8.39%, respectively. 2.89%

Table 3
Uncertainty around COVID-19 announcements.

Panel A: Event study of global effects of the WHO announcements on the options market

	Mean value	*p*-value
IVD	7.96	0.00%
VRPD	11.28	0.00%
SlopeD	9.96	0.07%

Panel B: Event study of global effects of the US lockdown on the options market

	Mean value	*p*-value
IVD	36.29	0.00%
VRPD	17.62	0.00%
SlopeD	27.65	0.00%

Panel C: Event study of local effects of the domestic lockdown on the options market

	Mean value	*p*-value
IVD	28.80	0.00%
VRPD	21.18	0.00%
SlopeD	37.09	0.00%

Panel D: Event study of effects of all announcements pooled over 28 countries on the options market

	Mean value	*p*-value
IVD	13.84	0.00%
VRPD	13.17	0.00%
SlopeD	15.17	0.00%

This table reports mean values of *IVD*, *VRPD*, and *SlopeD* across 28 countries in the event studies. In Panel A, *IVD*, *VRPD*, and *SlopeD* are calculated as in Eq. (3) and averaged for six WHO announcements which are listed in Panel A of Table A.1. Similarly, in Panel B and C, *IVD*, *VRPD*, and *SlopeD* are calculated as in Eq. (3) around the U.S. lockdown announcement on March 13, 2020 and around the domestic lockdown announcement in each country specified in Panel B of Table A.1, respectively. All countries and events are pooled together in Panel D. The mean values and corresponding *p*-values with country-fixed effects are reported. The mean values are given in percentage terms.

of *VRP* can be translated into a price premium of 10.0% in a Black–Scholes world, and −8.39% is translated into a price premium of −25.8%; that is, a 30-day ATM put option is 10.0% more (25.8% less) expensive than the same option priced at the average realized volatility level in the event (neighboring) window. Third, the positive mean *SlopeD* (9.96%) indicates a relatively higher price of the deeper OTM put options. The price premium for a 30-day OTM put option with $|\Delta| = 0.25$ (0.20) is 7.8% (9.4%) in the event window relative to the neighboring window. With the option going deeper OTM, such price premium becomes greater.

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[11] We use the one-sided confidence interval instead of a two-sided one because of our directional hypothesis that the estimates of mean *IVD*, *VRPD*, and *SlopeD* are positive.

[12] Among the countries that we study, we could not find evidence from the internet that the governments of Chili, South Korea, Sweden, and Taiwan imposed a national lockdown to combat COVID-19 during 2020.

[13] We also use the total COVID-19 cases, the daily new COVID-19 cases, and population as weights to test if the evidence is driven by specific countries in Table 3. The weighted averages yield closely similar results. We consider a further pre-COVID control sample at a similar time in 2019 and in 2015–2019 as tabulated in Table A.2.

[14] KPV state that, for ATM put options, a given percentage increase in IV is approximately equal to the same percentage increase in the option's price.

[15] The 24.8% price premium per year is calculated by the mean *IVD* (7.96%) divided by the average *IV* in the neighboring window (32.08%).

Table 4
COVID-19-induced policy uncertainty in the options market.

Dependent variable:	IV				VRP				Slope			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Stringency	0.10	0.10			0.07	0.06			0.45	0.46		
	(5.21)	(4.97)			(2.32)	(2.29)			(4.86)	(4.67)		
Cases			0.00				0.00				0.01	
			(1.96)				(1.93)				(0.77)	
Deaths				0.03				0.05				0.11
				(1.97)				(2.20)				(0.90)
Controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
R^2	7.4%	15.4%	12.3%	13.1%	4.1%	11.9%	12.1%	12.7%	4.6%	11.3%	10.9%	10.9%

This table shows the results from Fama and MacBeth (1973) cross-country regressions over our sample period from January 2020 to December 2020. Stringency is the 1-day lagged stringency index obtained from the Oxford COVID-19 Government Response Tracker. Cases and Deaths are the lagged rolling 7-day averages of the daily new confirmed cases and deaths, respectively. The lagged ETF return and the lagged government economic support index are used as control variables. Variables are given in percentage terms. The NW t-statistics are reported in parentheses.

4.3. Time-series analysis

We use the cross-country stringency index in the examination of the second hypothesis that uncertainty associated with the country-specific policy strictness is priced in the options market in the time series. Specifically, we follow the two-step procedure of Fama and MacBeth (1973) to conduct the country-level regressions. In the first step, we estimate the coefficients β_t in the following models for each country i on day t,

$$X_{i,t} = \alpha_t + \beta_t \text{Stringency}_{i,t-1} + \epsilon_{i,t}, \tag{4}$$

$$X_{i,t} = \alpha_t + \beta_t \text{Stringency}_{i,t-1} + \gamma_t Y_{i,t-1} + \epsilon_{i,t}, \tag{5}$$

where $X_{i,t}$ denotes the option market measures *IV*, *VRP*, and *Slope*, Stringency$_{i,t-1}$ is the lagged stringency index, and the control variable, $Y_{i,t-1}$ includes the ETF return and the government economic support index on day $t-1$ for country i.[16] In the second step, we calculate the time-series averages of the β_ts in 2020 with the NW t-statistics adjusted with six lags. The results are reported in Table 4. Stringency has a significantly positive coefficient in each specification with and without Y. The evidence supports our second hypothesis that there is a positive relation between the cost of option protection against the uncertainty caused by the strictness of the COVID-19-related policy responses. It is worth noting that the t-statistics of Stringency in regressions (2) and (5) are slightly smaller, though still statistically significant, than those of the others, indicating that the relation between Stringency and *VRP* might be less pronounced than *IV* and *Slope*. Put differently, *VRP* may deviate somewhat from the trend of Stringency. It is due to the severely volatile market condition resulting in abnormal *VRP*s, consistent with the significantly negative values of *VRP* that we observe in Table 2 and Fig. 2.

We also examine the effect of the daily COVID-19 case/death news on uncertainty by substituting the rolling 7-day average daily new confirmed cases or daily new deaths for Stringency into Eq. (5). The daily new cases and deaths are positively related to the option measures, which is consistent with the conjecture that the options that provide protection against COVID-19-induced uncertainty are more expensive with the pandemic getting more severe. However, the tail risk measure exhibits less sensitivity to news of the COVID-19 severity, for the coefficients of the cases and deaths are not statistically significant.[17]

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[16] The economic support index is also collected from Our World in Data (OWID) and provides a measure of government economic responses. It is calculated in a similar manner as the stringency index using two indicators, that is, the income support and debt/contract relief.

[17] Li et al. (2021) show that the severity of the COVID-19 pandemic, proxied by the daily new cases and deaths, has increased the cost of option protection against tail risk in the Chinese option market. However, we do not observe such causality on a global scale.

5. Conclusion

Uncertainty associated with the official responses to COVID-19 from around the globe and each country is priced in the options market. In this paper, we use the option measures constructed in KPV, namely, *IV*, *VRP*, and *Slope*, combined with an event study and a panel regression analysis, to test the impact of the COVID-19-related constraint advice and measures on the cost of option protection against the price risk, variance risk, and tail risk, respectively. We find that the cost of option protection against such uncertainty increases following the major WHO announcements, the lockdown announcements from governments, and stricter government restriction policies.

What we find in this study suggests that the investors demand a compensation in taking on the aforementioned uncertainty and pay a price premium to buy the option insurance against such uncertainty in the options market. This study can be extended to a longer period of time and include more public health crises in future work.

Appendix

We use an alternative event study methodology to test the price of COVID-19-induced uncertainty in the options market in 2020. Given the fast-paced evolution of COVID-19, the neighboring windows may reflect different sources of uncertainty (e.g., reduced uncertainty following the central bank intervention) and not account only for country-fixed effects or slow-moving time variation in volatility, we then consider pre-COVID control samples at a similar time in 2019 and in 2015–2019 as tabulated in Table A.2, that is, *XD*s from Eq. (3) are adjusted again for the base year 2019 and for the base years from 2015 to 2019. Specifically, we pool all the countries and all the announcements and calculate the mean differences between *XD*s in 2020 and in the pre-COVID control samples as in Eqs. (A.1) and (A.2) using the one-sided OLS test clustering the standard errors by country, the results of which are tabulated in Table A.2.

$$XDD = XD_{2020} - XD_{2019}, \tag{A.1}$$

$$XDD = XD_{2020} - \sum_{t=2015}^{2019} \frac{XD_t}{5}, \tag{A.2}$$

We require the options that we use to calculate *XD*s for each event to be in the same month, the same week within that month, and the same day of the week in all years. The results are consistent with those in Panel D of Table 3, calculated using the KPV method we specify in Section 2.2.

Table A.1
WHO and lockdown announcements.

Panel A: WHO announcements	
Date	Detail
30-Jan-2020	Declaration of PHEIC[a]
11-Mar-2020	Declaration of a pandemic
16-Apr-2020	Issuance of a guidance on "lockdowns"
13-Jun-2020	Announcement of Beijing outbreak
31-Aug-2020	Issuance of the first survey on the impact of COVID-19
29-Oct-2020	the World Health Summit

Panel B: Lockdown announcements			
Date	Country	Date	Country
19-Mar-2020	Australia	20-Mar-2020	Mexico
17-Mar-2020	Belgium	12-Mar-2020	Netherlands
27-Mar-2020	Brazil	23-Mar-2020	New Zealand
16-Mar-2020	Canada	03-Apr-2020	Singapore
–	Chile	23-Mar-2020	South Africa
23-Jan-2020	China	–	South Korea
16-Mar-2020	France	16-Mar-2020	Spain
16-Mar-2020	Germany	–	Sweden
23-Mar-2020	Hong Kong	16-Mar-2020	Switzerland
24-Mar-2020	India	–	Taiwan
16-Mar-2020	Indonesia	17-Mar-2020	Thailand
09-Mar-2020	Italy	20-Apr-2020	Turkey
27-Feb-2020	Japan	23-Mar-2020	United Kingdom
16-Mar-2020	Malaysia	13-Mar-2020	United States

This table lists the WHO announcements we study in the paper, the selecting process of which is described in Section 2.1, in Panel A, and the national lockdown announcement date for each country in Panel B.
[a]The Director-General declared the novel coronavirus outbreak a public health emergency of international concern (PHEIC) on January 30, 2020.

Table A.2
Uncertainty around COVID-19 announcements adjusted for the pre-COVID-19 samples.

Panel A: Relative to the base year 2019		
	Mean value	*p*-value
IVDD	15.34	0.00%
VRPDD	14.19	0.00%
SlopeDD	12.73	0.00%

Panel B: Relative to the average of the base years 2015–2019		
	Mean value	*p*-value
IVDD	17.02	0.00%
VRPDD	11.18	0.01%
SlopeDD	14.83	0.01%

This table reports the mean values of our focal variables relative to the base year 2019 and to the averages of five base years 2015–2019 across 28 countries around all the announcements we study in this paper, studying the effects of the WHO announcements, the global effects of the U.S. lockdown announcement, and the domestic lockdown announcements in each country, on the options market. *IVDD*, *VRPDD*, and *SlopeDD* around an announcement for each country are calculated as in Eq. (A.1) in Panel A and Eq. (A.2) in Panel B.

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