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Risk perception and oil and gasoline markets under COVID-19

Behzod B. Ahundjanov, Sherzod B. Akhundjanov, Botir B. Okhunjanov

1. Introduction

The novel coronavirus (COVID-19) exposed individuals to a great uncertainty about its health and economic ramifications, especially in the early days and weeks of the outbreak. This study documents oil and gasoline market implications of individuals’ behavior upon such uncertainty by analyzing the relationship between Google search queries related to COVID-19—information search that reflects one’s level of concern about the subject (risk perception)—and the performance of oil and gasoline markets during the pandemic. The empirical analysis based on daily data and a structural vector autoregressive model reveals that a unit increase in the popularity of COVID-19 related global search queries, after controlling for COVID-19 cases, results in 0.083% and 0.104% of a cumulative decline in Dow Jones US Oil & Gas Total index and New York Harbor Conventional Gasoline Regular spot price, respectively, after one day, 0.189% and 0.234% of a cumulative decline after one week, and 0.191% and 0.237% of a cumulative decline after two weeks. The reaction of Brent and West Texas Intermediate crude oil prices to the spike in COVID-19 related online searches is found to be statistically insignificant, which can be explained by oil price pass-through into gasoline spot price.

1. Introduction

The coronavirus disease 2019 (COVID-19) was first identified in Wuhan region of China in December 2019 (Zhu et al., 2020). Within a short period of time, the infectious disease has spread far and wide, with the World Health Organization declaring COVID-19 outbreak a global pandemic on March 11, 2020 (Cucinotta & Vanelli, 2020). As of July 2, 2020, the virus is believed to have infected more than 10.8 million people and contributed to over 520,000 of deaths worldwide. The increasing gravity of the situation induced large-scale social and behavioral changes as well as introduction of unprecedented policies, including travel restrictions, school and business closures, and stay-at-home orders. The global economy (Baldwin & di Mauro, 2020; Yılmazkuday, 2020a) and financial markets (Ahundjanov, Akhundjanov, & Okhunjanov, 2020a; Baker et al., 2020; Yılmazkuday, 2020c) have inevitably felt the brunt of such measures. Understanding the economic and financial and commodity market implications of individuals’ behaviors under a pandemic represents an important consideration, both for policy design and financial strategy and planning.

In this article, we study one specific behavioral attribute of individuals under a pandemic: information search or, equivalently, risk perception.
exception. To understand oil and gasoline market implications of individuals’ behavior upon such uncertainty, we explore the relationship between Google search queries related to COVID-19—information search—and the performance of oil and gasoline markets. Our empirical analysis is based on daily data between January 22, 2020 and July 2, 2020 and a structural vector autoregressive (SVAR) model, where the endogenous variables are the percentage change in daily global Google search queries related to COVID-19 and the percentage change in daily oil and gasoline market price (Brent crude oil price, West Texas Intermediate crude oil price, New York Harbor Conventional Gasoline Regular spot price, Dow Jones US Oil & Gas Total index). Because COVID-19 is an exogenous shock, the percentage change in daily global COVID-19 confirmed cases (and deaths) is included in this framework as an exogenous variable, similar to Ahundjanov et al. (2020a) and Yilmazkuday (2020a), Yilmazkuday (2020b) and Yilmazkuday (2020c).

Our strategy to use Google search queries to capture information search or risk perception is in line with previous studies1 and concurrent work on COVID-19 (Ahundjanov et al., 2020a; Amstad, Cornelli, Gambacorta, & Xia, 2020; Barrios & Hochberg, 2020; Papadamou, Fassas, Kenourgios, & Dimitriou, 2020). As Da et al. (2011) pointed out, “aggregate search frequency in Google is a direct and unambiguous measure of attention” which allows for “capturing investor attention in a more timely fashion”. Further, Tett (2013) noted that, in light of growing importance of online search and social platforms, individuals and investors can manage and track investments with greater precision by tapping those platforms. Ginsberg et al. (2009) find a robust correlation between influenza epidemics and health-seeking behavior of individuals in the form of online search activities. COVID-19-related search queries are essentially a proxy for the demand for information about the virus which reflects an individual’s level of concern about the subject. Hence, the higher the search share, the higher the perceived risk among population, which translates to more intense financial and commodity market activities due to hedging against perceived risk. Anecdotal evidence in support of this hypothesis appears in Fig. 1, which shows the time series plots of global Google search queries related to COVID-19 (2nd panel) and major oil and gasoline market prices (3-6th panels) analyzed in this study. It is apparent that Google search (especially, search queries containing the term “Coronavirus”) and oil and gasoline market dynamics are largely a mirror image of each other about the time axis.

The results from formal empirical analyses suggest that a unit increase (shock) in the combined popularity of all Google search queries related to COVID-19 (i.e., the sum of all COVID-19-related queries considered in this study) is associated with 0.083% and 0.104% of a cumulative decline in Dow Jones US Oil & Gas Total index and New York Harbor Conventional Gasoline Regular spot price, respectively, after one day, 0.189% and 0.234% of a cumulative decline after one week, and 0.191% and 0.237% of a cumulative decline after two weeks. Our findings are robust to a range of alternative specifications, including controlling for COVID-19 deaths, a global economic activity, and the Russia–Saudi Arabia oil price war of 2020.

Similar to trends seen in some concurrent studies (e.g., Papadamou et al., 2020; Yilmazkuday, 2020d), we also perform analysis with a specific COVID-19 related search query (specifically, “Coronavirus”) as opposed to aggregate search queries related to COVID-19. The findings from this analysis suggest that a unit increase (shock) in the popularity of Google search queries containing the term “Coronavirus” is associated with 0.068% of a cumulative decrease in Dow Jones US Oil & Gas Total index after one day, 0.135% of a cumulative decrease after one week, and 0.137% of a cumulative decrease after two weeks. Clearly, these estimates are lower in magnitude than their counterparts reported for the analysis with aggregate search queries. More importantly, the reaction of New York Harbor Conventional Gasoline Regular spot price becomes statistically insignificant in this case. While “Coronavirus” is indeed the most popular search query among COVID-19 related search queries (see Fig. 2), it nonetheless does not capture all or most online searches related to COVID-19, particularly in the latter half of the study period. This exercise, in and of itself, represents a non-negligible contribution as it underscores the importance of considering aggregate search queries related to COVID-19 (as opposed to a single query) for sound empirical analysis and inferences.

The effect of online search activities on Brent and West Texas Intermediate crude oil prices is found to be statistically insignificant, both with popular search query “Coronavirus” and total search queries related to COVID-19. This observation can be explained by overpass-through of crude oil price into gasoline spot price (Yilmazkuday, 2020b), analysis which is beyond the scope of this paper. Our back of the envelop calculations indicate that, in this context, 1% increase in daily crude oil price results in 1.664% increase in daily gasoline spot price after one week and 1.689% increase after two weeks, which is suggestive of overpass-through.

Our study lies at the intersection of nascent literature on behavioral aspects of COVID-19 (Ahundjanov et al., 2020a; Barrios & Hochberg, 2020) and oil and gasoline market implications of the pandemic (Albulescu, 2020; Yilmazkuday, 2020b). The endeavor

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1 Examples include applications in finance (Da, Engelberg, & Gao, 2011; Kostopoulos, Meyer, & Uhr, 2020; Vlastakis & Markellos, 2012), financial economics (Dergiades, Milas, & Panagiotidis, 2015), monetary economics (Altavilla & Giannone, 2017; Wohlfarth, 2018), labor economics (Baker & Fradkin, 2017; D’Amuri & Marucci, 2017), and sales and tourism (Choi & Varian, 2012), among others. An important distinction between these studies and our paper is the type of Google search queries considered. Specifically, prior literature focused on search queries related to, for instance, individual stocks (e.g., company name and ticker symbol) or the economy (e.g., “financial crisis”, “recession”, “bankruptcy”, “deficit”, “unemployment”, and “inflation”). In contrast, we focus on pandemic-related search queries, which represent a fundamentally different type of concern.

2 There are three other approaches proposed in the literature to measure investor attention/risk attitude: (i) market-based indices (e.g., trading volume, turnover, extreme returns); (ii) survey-based indices; and (iii) news-based indices (i.e., keywords or firm coverage in news media). The approach adopted in this study (online search-based indices) is popularized by the seminal work of Da et al. (2011) and it improves upon the other approaches in terms of capturing investor attention, which explains the widespread use of online searches to proxy attention, information search, or, equivalently, risk attitude in the recent literature.
Fig. 1. Time series plots of study variables between January 22, 2020, and July 2, 2020. Google Trends shows the popularity of global search queries containing the term “Coronavirus”, “COVID”, “COVID 19”, “COVID-19”, or “COVID19”, which are commonly used to refer to the novel coronavirus. Google Trends data here shows the absolute trends for each of the five search queries. Fig. 2, on the other hand, shows the relative trends for the five queries. A value of 100 is the peak popularity for a search query, while a value of 0 is the lowest popularity.
undertaken here bridges these two lines of literature, furthering our understanding of oil and gasoline market consequences of individuals’ risk perception under a pandemic, which is essential for policy design and financial strategy and planning. As such, our study contributes to a broader literature exploring the effects of risk perception on economic choice (Arrow, 1982). We do not attempt, nor claim, to establish any causal relationship between individuals’ risk perception and the performance of oil and gasoline markets during the pandemic. In that sense, our work is similar to recent literature exploring associations between information search and investor behavior (see, for instance, Amstad et al., 2020; Kostopoulos et al., 2020).

The remainder of the paper is organized as follows. The next section reviews the related literature in this area. Section 3 provides a theoretical basis to understand the relationship between risk perception and energy markets under a pandemic. In Section 4, we describe the data used in empirical analysis, while in Section 5 we discuss our empirical approach. The results and discussions are provided in Section 6 and robustness checks in Section 7. Section 8 offers some concluding remarks.

2. Literature

The literature on COVID-19 implications on oil and gasoline markets is gradually forming. Albulescu (2020), analyzing crude oil price reaction to COVID-19, shows that an increase in COVID-19 confirmed cases has a marginal negative effect on crude oil prices in the long-run. Focusing on oil-stock nexus during the pandemic, Salisu, Ebuh, and Usman (2020) report that both oil and stock markets may experience greater impacts of own and cross shocks during the pandemic than the period before it. Further, the study shows that the probability of observing negative oil and stock returns during the pandemic is mainly attributable to uncertainty associated with the corresponding markets. Prabheesh, Padhan, and Garg (2020) extend the analysis of the nexus between oil prices and stock market returns to net oil-importing countries.

Examining the impact of the outbreak on individual US oil and gas producers, Iyke (2020) finds that firms’ return and return volatility react to COVID-19 heterogeneously. Corbet, Goodell, and Günay (2020), analyzing volatility spillovers and volatility co-movements among energy-producing, extracting, and transporting corporations’ stock prices during the COVID-19 pandemic, find positive and economically meaningful spillovers from falling oil to both renewables and coal. Similarly, Chang, McAleer, and Wang (2020) study investor herding behavior—investor psychology to follow the performance of others—in the renewable energy markets to explain the volatility of stock returns during the COVID-19 pandemic.
Yilmazkuday (2020b) investigates the pass-through of crude oil prices into gasoline prices during the volatile COVID-19 period. The author finds that 1% increase in daily oil prices results in about 1.4% increase in daily gasoline spot prices after one week and 1.6% increase after two weeks, which corroborate our own estimates of overpass-through reported above.

Our study deviates from these studies by focusing on a crucial link between COVID-19 and oil and gasoline markets (while controlling for COVID-19 cases): information search, or, equivalently, risk perception. We show that the correlation of oil and gasoline market prices/index is orders of magnitude stronger with Google search queries related to COVID-19 than with COVID-19 confirmed cases (or COVID-19 related deaths). Consequently, the present paper contributes to this emerging line of literature by providing a more complete picture of the implications of COVID-19 on oil and gasoline markets.

3. Conceptual model

Pandemics expose individuals, investors, firms, and policy makers to a great uncertainty about how they are going to unfold: the extent of individual health risks and economic and employment prospects during and in the aftermath of a pandemic. Such uncertainty inevitably contributes to an individual stakeholder’s risk perception, which is a key psychological factor guiding one’s behavioral change and economic choice (Arrow, 1982; Kostopoulos et al., 2020).

Individuals’ risk perception, level of uncertainty, and expectations about future are shaped by information. The importance of demand for information in financial and commodity markets is theoretically well established (see, for a review of the literature, Vlastakis & Markellos, 2012). In the spirit of Barrios and Hochberg (2020), consider an investor who consumes information through (online) media outlets. In face of a pandemic, a rational investor attempts to learn about the new virus, its severity and geographic reach, and, more importantly, projections regarding how the pandemic may play out. Based on this information, the investor forms an expectation about economic environment in the short-and/or long-run (e.g., higher probability weight on the dis-favorable scenario), which ultimately determines her decision about if/how to adjust her financial portfolio in order to hedge against the perceived risk. Depending on the severity of the health threat and its duration, as well as the level of scientific understanding of the outbreak itself, the investor can make repeated visits to the media outlet in order to continuously update her priors and, accordingly, adjust her portfolio.

As a result, the main channel through which risk perception (under a pandemic) can influence energy markets is through energy investment. The energy markets become more volatile if investors have bleak expectations (which are formed after consuming information) for key factors on investment spending, such as, demand for oil, during and in the aftermath of the pandemic. As the International Energy Agency (2020) stated:

Almost all investment activity has faced some disruption due to lockdowns, whether because of restrictions on the movement of people or goods, or because the supply of machinery or equipment was interrupted. But the larger effects on investment spending in 2020, especially in oil, stem from declines in revenues due to lower energy demand and prices, as well as \textbf{more uncertain expectations for these factors in the years ahead}.

4. Data

We collected daily data for the period between January 22, 2020 (the start date of the COVID-19 data set) and July 2, 2020 for three groups of variables: (i) global COVID-19 confirmed cases, (ii) COVID-19 related worldwide Google search queries, and (iii) oil and gasoline market prices. The data on COVID-19 confirmed cases comes from the Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE).

The data on COVID-19-related online search queries comes from Google Trends. We collected data for global search queries containing one of the five common terms used to refer to the novel coronavirus: “Coronavirus”, “COVID”, “COVID 19”, “COVID-19”, and “COVID19”. Google search queries are not case sensitive. Google Trends data, which ranges from 0 to 100, represents search interest relative to the highest point on the chart for the given region and time. So, a value of 100 is the peak popularity for a search query, while a value of 0 is the lowest popularity. Fig. 2 reports the relative trends of the five queries considered in this study. Clearly, “Coronavirus” has been the most popular search query during the study period, which explains its widespread use in the concurrent COVID-19 literature (Amstad et al., 2020; Papadamou et al., 2020). Therefore, it is our first information search variable of interest. We also sum the data for five queries to obtain the total (combined) search volume over the study period, and use it as our second and main information search variable of interest. The reason for performing analysis with these two variables is to demonstrate the sensitivity of our empirical results to the chosen online search variable.

Oil and gasoline market data includes daily data (at market close) of Dow Jones US Oil & Gas Total (DWCOGS) Stock Market Index, which comes from Yahoo!Finance, and Brent (DCOILBRENTEU) crude oil price, West Texas Intermediate (DCOILWTICO) crude oil price, and New York Harbor Conventional Gasoline Regular (DGASNYH) spot price, which come from FRED, Federal Reserve Bank of

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3 While the study by Narayan (2020) is similar in spirit to our study, there is a significant difference between the two studies. In particular, Narayan’s (2020) work explores the effect of COVID-19 infections and oil price news on oil market prices, whereas our work zeros in on the association between information search related to COVID-19 (i.e., risk perception) and energy markets.

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4 The data is publicly available at https://github.com/CSSEGISandData/COVID-19.

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5 The data is publicly available at https://trends.google.com/trends.

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6 The data is publicly available at https://finance.yahoo.com/.
column), the Augmented Dickey Fuller (ADF) test is performed for variables in levels (second to last column) as well as variables transformed to daily percentage changes (last column). The null hypothesis for the ADF test is a series has a unit root. Significance of the ADF test statistics are indicated as follows: *** p < 0.01, ** p < 0.05, * p < 0.10.

St. Louis. For consistency with other data sets, the missing observations in oil and gasoline market data (due to weekends and holidays) are linearly interpolated, which is a standard approach in the literature.

Table 1 reports the summary statistics for the study variables. The time series plots appear in Fig. 1. It is apparent that an increase in global COVID-19 confirmed cases has triggered an online interest—information search—for it, with search query “Coronavirus” reaching a peak popularity on March 15, 2020. The evolution of oil and gasoline market prices over the study period is largely the mirror image that of Google Trends queries (especially that of “Coronavirus”) about the time axis. This anecdotally shows the reaction of individuals and investors (upon information search) to the pandemic in terms of their oil and gasoline market decisions. Fig. A.1 in the appendix presents further evidence in this regard. Specifically, oil and gasoline market prices are strongly correlated with Google search queries related to COVID-19, with the correlation coefficients ranging from −0.79 to −0.94 for total Google search queries. In contrast, the correlation between oil and gasoline market prices and COVID-19 confirmed cases (COVID-19 related deaths) ranges from −0.08 to −0.19 (−0.15 to −0.22, respectively). This observation alone underscores the importance of information search (risk perception) in explaining oil and gasoline market implications of the pandemic.

5. Methodology

A structural vector autoregressive (SVAR) model is implemented to investigate the relationship between Google information search and oil and gasoline market performance during the COVID-19 pandemic. An advantage of a SVAR framework is that it allows to identify shocks and trace them over time via impulse response function. Let \( y_t = (\Delta g_t, \Delta o_t) \) be a bivariate vector of endogenous variables in period \( t \), where \( \Delta g_t \) is the percentage change in daily global Google search queries related to COVID-19 (“Coronavirus”) or the sum of five queries reviewed in Section 4; and \( \Delta o_t \) is the percentage change in daily oil and gasoline market price (Brent crude oil price, West Texas Intermediate crude oil price, New York Harbor Conventional Gasoline Regular spot price, or Dow Jones US Oil & Gas Total index). Because COVID-19 is exogenous shock, we include the percentage change in daily global COVID-19 confirmed cases \( \Delta c_t \) as an exogenous variable, similar to Ahundjanov et al. (2020a) and Yilmazkuday (2020a, 2020b, 2020c). As reported in Table 1 (last column), the Augmented Dickey–Fuller test for the study variables (i.e., \( \Delta g_t, \Delta o_t, \Delta c_t \)) strongly rejects the null hypothesis of a unit root.

Formally, the SVAR model is specified as:

\[
Ay_t = a + \sum_{i=1}^{p} A_i y_{t-i} + \Phi \Delta c_t + u_t, 
\]

where \( u_t \) is the vector of mutually and serially uncorrelated structural errors (innovations). The optimal lag order \( p \) is determined based on Schwarz criterion from the candidate models containing 1–15 number of lags of \( y_t \). For estimation purposes, it is conventional to

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**Table 1**

Summary statistics for study variables.

| Variable | Mean      | Median    | St. Dev.  | Min      | Max      | ADF (for levels) | ADF (for % change) |
|----------|-----------|-----------|-----------|----------|----------|------------------|--------------------|
| COVID-19 confirmed cases | 2,984,100.72 | 1,845,951.00 | 3,234,166.45 | 555.00 | 10,871,926.00 | 0.673 | -12.832*** |
| Google: Coronavirus | 30.63 | 21.00 | 25.59 | 4.00 | 100.00 | -1.621 | -4.986*** |
| Google: Total | 183.53 | 166.00 | 131.41 | 4.00 | 465.00 | -1.660 | -5.065*** |
| Brent (DCOILBRENTEU) | 36.63 | 35.33 | 14.33 | 9.12 | 62.11 | -0.869 | -4.683*** |
| West Texas Intermediate (DCOILWTICO) | 33.78 | 34.70 | 14.44 | -36.98 | 56.76 | -1.333 | -5.091*** |
| New York Harbor, Regular (DGSNYH) | 1.04 | 1.00 | 0.38 | 0.43 | 1.70 | -0.867 | -3.984** |
| Dow Jones US Oil & Gas Total (DWCOGS) | 3,026.97 | 2,893.20 | 677.24 | 1,781.57 | 4,388.71 | -1.530 | -4.236*** |

**Note:** ‘Google: Coronavirus’ is search query containing the term “Coronavirus” and so on, while ‘Google: Total’ is the sum of five search queries: “Coronavirus”, “COVID”, “COVID 19”, “COVID-19”, and “COVID19”. The Augmented Dickey-Fuller (ADF) test is performed for variables in levels (second to last column) as well as variables transformed to daily percentage changes (last column). The null hypothesis for the ADF test is a series has a unit root. Significance of the ADF test statistics are indicated as follows: *** p < 0.01, ** p < 0.05, * p < 0.10.

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7 The data is publicly available at https://fred.stlouisfed.org.
8 For robustness, we also employed imputation by spline interpolation and Kalman smoothing (Moritz & Bartz-Beielstein, 2017). Our main estimation results, which are available upon request, were qualitatively unaffected. We also considered the analysis by aggregating COVID-19 cases and Google search data over the weekends and holidays. Again, our main results were qualitatively unaltered.
9 For further information about the statistical properties (size distribution and growth process) of COVID-19 infections, see Ahundjanov, Akhundjanov, and Okhunjanov (2020b).
10 Percentage change in variable \( x \) (e.g., COVID-19 online searches or oil/gasoline market prices) is defined as \( \Delta x_t = (x_t - x_{t-1})/x_{t-1} \). Such formulation of the study variables also removes unit roots in these variables (see Table 1). For robustness, we determined the lag order \( p \) using two different packages in R (R Core Team, 2020): tsDyn and vars packages (Pfaff, 2008). Both methods produced the same optimal lag orders for the models analyzed in this article.
express equation (1) in reduced form as follows:

$$y_t = A^{-1}a + \sum_{k=1}^{p} A^{-1}A_k^* y_{t-k} + A^{-1}\Phi \Delta \psi + A^{-1}u_t$$

$$= b + \sum_{k=1}^{p} B_k^* y_{t-k} + \Omega \Delta \psi + \epsilon_t$$

(2)

where $A^{-1}$ is the structural impact multiplier matrix which has a recursive structure such that the reduced form errors $\epsilon_t$ can be decomposed as $\epsilon_t = A^{-1}u_t$. The size of the shocks is standardized to unity, so that the identification is by triangular factorization (Lütkepohl, 2007). The recursive structure of $A^{-1}$ inherently necessitates an ordering of endogenous variables in $y_t$ to allow a proper transmission of the shocks. We order the variables as $y_t = (\Delta g_t, \Delta o_t)^T$, which implies shocks in $\Delta g_t$ (i.e., Google search) can affect $\Delta o_t$ (i.e., oil and gasoline market price), which is the main interest of our study. To allow shocks from $\Delta o_t$ to also affect $\Delta g_t$, thereby allowing the interaction between the two variables, we do not impose any block exogeneity.\(^\text{12}\)

We estimate the SVAR model in Eq. (2) by Bayesian inference (An & Schorfheide, 2007), using bvartools package in R (R Core Team, 2020). In particular, we use independent normal-Wishart priors\(^\text{13}\) and perform a total of 10,000 iterations of the Gibbs sampler to obtain the posterior draws, of which the first 5000 is dropped as burn-in draws. The remaining 5000 is used for inferences and to build a structural impulse response function (IRF). The IRF allows to explore the dynamic interactions between the endogenous variables by illustrating the simulated impact of a unit change (shock) in variable $i$ to variable $j$ at time $s$, for $s = 1, 2, ..., n$. We report a cumulative IRF to show the cumulative response of oil and gasoline market prices to a unit change (shock) in Google search queries related to COVID-19.

### 6. Main results

The main estimation results appear in Table 2 and Fig. 3, which report the cumulative impulse responses of oil and gasoline market prices (Brent crude oil price, West Texas Intermediate crude oil price, New York Harbor Conventional Gasoline Regular spot price, and Dow Jones US Oil & Gas Total index) to a unit change (shock) in the popularity of COVID-19-related Google search (“Coronavirus” or the sum of five COVID-19-related search queries) for different time horizons.

The results suggest that one unit increase (shock) in the combined popularity of all Google search queries related to COVID-19 (i.e., the sum of all COVID-19-related queries considered in this study) is associated with 0.083% and 0.104% of a cumulative decline in Dow Jones US Oil & Gas Total index and New York Harbor Conventional Gasoline Regular spot price, respectively, after one day, 0.189% and 0.234% of a cumulative decline after one week, and 0.191% and 0.237% of a cumulative decline after two weeks. As

\(^\text{12}\) For robustness, we also estimated the model by imposing block exogeneity, so that shocks in $\Delta o_t$ do not affect $\Delta g_t$ contemporaneously. The estimation results, which are available upon request, were qualitatively unaffected.

\(^\text{13}\) For robustness, we also estimated the model using uninformative priors, and obtained similar results.
evident from Fig. 3, these effects converge to their long-run levels in about one week. On the other hand, the analysis of a specific COVID-19 related search query (as opposed to aggregate search queries related to COVID-19) suggests that a unit increase (shock) in the popularity of Google search queries containing the term “Coronavirus” is associated with 0.068% of a cumulative decrease in Dow Jones US Oil & Gas Total index after one day, 0.135% of a cumulative decrease after one week, and 0.137% of a cumulative decrease after two weeks. Importantly, the reaction of New York Harbor Conventional Gasoline Regular spot price is statistically insignificant in this context. Overall, our analysis indicates that the cumulative responses of energy markets are more pronounced and likely to be statistically significant for changes in total volume of internet searches related to COVID-19 than for changes in search volume of a single query (i.e., “Coronavirus”). Although this observation is rather unsurprising, given that total volume of search queries subsumes “Coronavirus” afterall, it is yet not reflected in empirical work on COVID-19 (Papadamou et al., 2020; Yilmazkuday, 2020d).

Further, we find the effect of online search activities on Brent and West Texas Intermediate crude oil prices to be statistically insignificant for search queries containing the term “Coronavirus” as well as total search queries related to COVID-19: credible
The insignificant relationship between online search and crude oil prices can be rationalized in terms of well-documented crude oil price pass-through into gasoline prices (Bachmeier & Griffin, 2003; Borenstein et al., 1997). Although the formal analysis of this hypothesis is beyond the scope of this paper, we offer some back of the envelop calculations in what follows.

Similar to Shambaugh (2008), Forbes, Hjortsoe, and Nenova (2018), and Ha, Marc, and Yilmazkuday (2020), we use a ratio of cumulative responses to define pass-through. Specifically, the crude oil price pass-through into gasoline spot price is defined as the ratio of cumulative response of New York Harbor Gasoline Regular spot price (following a percentage change in total Google search queries) to cumulative response of Brent Crude Oil price (following a percentage change in total Google search queries):
Our results suggest that a 1% increase in daily crude oil price results in about 1.664% increase in daily gasoline spot price after one week and 1.689% increase after two weeks, which is indicative of overpass-through. These estimates are consistent with those of Yilmazkuday (2020b), who formally studies the pass-through of crude oil prices into gasoline prices during the volatile COVID-19 period. The author’s findings show that a 1% increase in daily oil prices results in about 1.4% increase in daily gasoline spot prices after one week and 1.6% increase after two weeks. While these estimates largely support our own estimates, the slightly elevated estimates in our case can be attributed to the inclusion of Google information search related to COVID-19—a variable that is highly correlated with oil and gasoline market prices—in our study, in addition to COVID-19 cases. As such, our analysis presented here provides a more complete picture of the implications of the COVID-19 pandemic on oil and gasoline markets.

\[
\text{Pass-through} = \frac{\text{Cumulative response of gasoline spot price}}{\text{Cumulative response of crude oil price}}
\]
7. Robustness checks

To guard against the confounding effects of other factors on our findings, we performed a range of robustness checks. First, to control for the possible lagged effects of COVID-19 confirmed cases, we estimated Eq. (2) with lagged COVID-19 cases ($\Delta c_{t-1}$) as an additional control (see Fig. 4). Second, granted that COVID-19 related deaths can potentially trigger a greater level of concern than COVID-19 confirmed cases, we also estimated Eq. (2) using COVID-19 related deaths ($\Delta d_t$) as an exogenous variable (see Fig. 5). Third, given that the maximum of the Google trend index for a given query is 100, the sum of COVID-19-related queries (to get total Google search queries) may be viewed as not particularly appealing. To demonstrate the robustness of our main findings to an alternative definition of combined online searches, we also consider a “value weighted index”, which essentially measures the combined index by assigning time-varying weights to each COVID-19-related Google query. The solid lines correspond to the Bayesian estimates, while the shaded regions represent 95% credible intervals.

Fig. 6. Cumulative effects of the value-weighted online searches on oil and gasoline markets. The value-weighted index measures the combined index by assigning time-varying weights to each COVID-19-related Google query. The solid lines correspond to the Bayesian estimates, while the shaded regions represent 95% credible intervals.
assigning time-varying weights to each COVID-19-related Google query (see Fig. 6). Fourth, given that energy markets are tightly intertwined with global economic activities, we also considered a global economic activity measured by the Baltic Exchange Dry Index (BDI) as an additional endogenous variable in Eq. (2). The BDI, published daily by the Baltic Exchange in London, effectively represents the changes in the global real activity and has been used extensively in the recent literature (Fan & Xu, 2011; Kilian, 2009; Makridakis, Merikas, Merika, Tsionas, & Izzeldin, 2020). Last but not least, on March 8, 2020, Saudi Arabia initiated a crude price war with Russia (commonly known as the Russia–Saudi Arabia oil price war of 2020) by discounting its crude and raising production, which crashed oil prices by as much as 30% (Raval & Sheppard, 2020). The price war ended on April 9, 2020, when the two sides (and other OPEC members) agreed to cut their output by more than a fifth (Reed, 2020). Given our study period encompasses the Russia–Saudi Arabia oil price war, we perform our analysis by explicitly controlling for the price war (see Fig. 7). In particular, we introduce in Eq. (2) a dummy variable (Iyke, 2020), which takes the value of one for the period between March 8, 2020 and April 9, 2020, and zero otherwise. Our main findings remain robust to all of these alternative specifications.

Fig. 7. Cumulative effects of online searches on oil and gasoline markets (controlling for the Russia–Saudi Arabia oil price war of 2020). Left panel: the effects for Google search query “Coronavirus”. Right panel: the effects for total Google search queries related to COVID-19, which is the sum of five search queries: “Coronavirus”, “COVID”, “COVID 19”, “COVID-19”, and “COVID19”. The solid lines correspond to the Bayesian estimates, while the shaded regions represent 95% credible intervals.
8. Conclusion

The COVID-19 has subjected the world to unprecedented challenges, inflicting health crisis and spawning economic turmoil. The social and economic costs of this pandemic are enormous and yet to be fathomed. In this study, we have investigated oil and gasoline market implications of individuals’ behavior upon a pandemic by analyzing the relationship between Google search queries related to COVID-19—information search—and the performance of oil and gasoline markets. The empirical analysis is carried out using daily data between January 22, 2020 and July 2, 2020, in conjunction with a structural vector autoregressive (SVAR) model, where the endogenous variables are the percentage change in daily global Google search queries related to COVID-19 and the percentage change in daily oil and gasoline market price (Brent crude oil price, West Texas Intermediate crude oil price, New York Harbor Conventional Gasoline Regular spot price, Dow Jones US Oil & Gas Total index).

Our findings suggest that a unit increase in global search interest of COVID-19, after controlling for COVID-19 cases, results in 0.083% and 0.104% of a cumulative decline in Dow Jones US Oil & Gas Total index and New York Harbor Conventional Gasoline Regular spot price, respectively, after one day, 0.189% and 0.234% of a cumulative decline after one week, and 0.191% and 0.237% of a cumulative decline after two weeks. The effect of online search activities on Brent and West Texas Intermediate crude oil prices is determined to be statistically insignificant, which is explained by overpass-through of crude oil price into gasoline spot price. The endeavor undertaken in this study furthers our understanding of the nature and magnitude of energy market implications of individuals’ behavior—specifically, risk perception—during the COVID-19 pandemic, which is important for policy design and financial strategy and planning.

Appendix A

Fig. A.1

References

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