COVID-19 and Market Expectations: Evidence from Option-Implied Densities

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Abstract

We compare risk-neutral densities from equity index options across several markets during the early phase of the COVID-19 pandemic. These densities reflect market expectations regarding its economic impact. The markets reacted abruptly and simultaneously initially, but with a marked time lag after ignoring the first clear warning signs for several weeks. As the crisis unfolds, option prices increasingly reflect differences in anticipated impact on and economic resiliency of these markets.

Keywords: COVID-19; Risk-neutral Densities; Equity Index Options

JEL classification: G01; G13

1. Introduction

Starting in Q1 2020, the COVID-19 pandemic has caused major disruptions to societies and economies worldwide. Economic activity has been severely impacted by lockdowns, massive travel restrictions, and other measures taken by many countries to slow down the spreading of the virus. This global health crisis is unprecedented in the modern era of a globalized economy. In its early phase, new and sometimes contradictory information came

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in almost by the minute, which made it difficult to forecast the pandemic’s economic impact, both short- and long-term.

A number of papers written in the first half of 2020 deal with the pandemic’s economic and financial effects. Some of them analyze reactions at the individual stock level and differences in the cross-section (Albuquerque et al., 2020; Bretsch er et al., 2020; Cejnek et al., 2020; Ding et al., 2020; Hassan et al., 2020; Pagano et al., 2020; Ramelli and Wagner, 2020), while others investigate reactions at the aggregate or market level (Alfaro et al., 2020; Croce et al., 2020; Gerdig et al., 2020; Gormsen and Koijen, 2020; Ru et al., 2020). Most of these studies combine information on stock returns and dividends with other economic and health data describing the state of the pandemic in different parts of the world.

In the present paper, we use information implied in prices of equity index options from six different markets (US, Japan, UK, Germany, France, Italy) to analyze how the pandemic’s financial impact was anticipated by equity option markets. From the emerging literature described above, Gormsen and Koijen (2020) is most closely related in analyzing aggregate market development using derivatives prices. While they derive lower bounds and point estimates for dividend growth and GDP growth from dividend futures, we estimate implied densities from option prices. The latter provide richer information than just point estimates. This allows us to gain insights into questions such as when the markets started to react, how severe the economic impact was estimated to be for different time horizons, and how these estimates changed as the pandemic unfolded in its first wave. With the benefit of hindsight, the actions of decision makers such as politicians or managers before the global spreading of the pandemic were viewed by many observers as too late, but one open question is what estimates they should/could have had at what time. Given that financial markets quickly incorporate new information into market prices, the insights gained from this analysis provide some indication regarding these questions. Expecting decision makers to be quicker in processing information than financial markets is difficult to justify.

Electronic copy available at: https://ssrn.com/abstract=3616625
2. Data

We use daily data from equity options on six stock indices: the S&P 500, FTSE 100, Nikkei 225, DAX 30, CAC 40, and FTSE MIB. For all these options, implied volatility surfaces of constant-maturity options, spot index values $S_t$, as well as risk-free interest rates $r_{t,T}$ in the respective currencies are downloaded from Thomson Reuters Eikon. For each day $t$ in our sample and each (constant) option maturity $(T-t)$, implied volatilities are available for moneyness ratios from 50% to 150% (defined as $F_{t,T}/K$, where $F_{t,T}$ is the forward index value and $K$ is the option strike). Maturities selected for our analysis are 3M, 6M, 1Y, and 2Y. The sample period starts on July 1, 2019, way before the increase in suspicious pneumonia cases in Wuhan, which later turned out to be caused by a new type of coronavirus. Observations are included until May 25, 2020.

Our sample allows for comparisons across countries that differ regarding when and how hard they were hit by the pandemic, both in terms of confirmed cases and related deaths. For all six countries, these statistics are illustrated in Fig. 1, where numbers are provided per mio. residents. Italy was the first country where cases increased sharply, followed by Germany and France. Cases in the US and UK initially lagged a few days behind, but soon exceeded those in the continental European countries. In comparison, Japan showed only a negligible number of cases. While Italy also suffered the highest number of deaths for a long time, the death toll in the US and in Germany was much lower and the curve much flatter compared to the other European countries.

3. Methodology

Denote the time $T$ risk-neutral density (RND) of the forward index value $F_{t,T}$ as seen at time $t < T$ by $\phi_{t,T}(\cdot)$. If a smooth strike-continuum of expiry $T$ call option prices were observable at time $t$, Call$_{t,T}(K)$, then this density could be inferred in a model-free way. As
shown first by Breeden and Litzenberger (1978) we have

\[ \phi_{t,T}(y) = e^{r(T-t)} \frac{\partial^2 \text{Call}_{t,T}(K)}{\partial K^2} \bigg|_{K=y}. \]  

(1)

In reality, only a discrete set of strikes are available. The volatility surfaces used in this paper provide 17 strikes for each \((t, T)\) pair in our observations. This means that a considerable amount of smoothing and curve fitting is needed before equation (1) can be used to produce sensible numbers. Figlewski (2010, Section 2) provides a taxonomy of methods that are used for this purpose. We prefer to use the non-parametric clamped spline approach proposed by Malz (2014), which is designed to avoid arbitrage opportunities that may arise for other non-parametric approaches. This algorithm is robust and straightforward to implement.

The resulting RNDs and their statistics such as quantiles can be compared over time and across markets. This provides insights to the markets’ forecasts regarding the indices’ future development. While the DAX is a performance index \(F_{t,T} = S_t e^{r(T-t)}\), the other
five indices are price indices \( F_{L,T} = S_t e^{(r_t T-t)q(T-t)} \), where \( q \) is the dividend yield). To make expectations comparable across indices, we will adjust all price indices for the impact of dividends, as is the case for the DAX by construction. To this end, we assume that the implied volatilities we get for the options on price indices are identical to those we would observe for (hypothetical) options on the performance variant of these indices. More precisely, for all RNDs estimated in this paper, we assume that dividends are reinvested, and reported implied volatilities are for a moneyness ratio of \( S_t e^{r_t T-t} \).

4. Results

The development of the resulting RNDs over time is illustrated in a Shiny app,\(^1\) which provides a comparison across indices for any day between July 1, 2019 and May 25, 2020. As an illustrative example for the app’s output, Figure 2 shows densities for the S&P 500 (top) and the FTSE MIB (bottom), both from February 24 (left) and March 16 (right). In all graphs, the gray densities shown for comparison are from February 20.

The RNDs from all six markets in our sample do not show any visible reactions or unusual behavior until mid-February. Our interpretation of this observation is that financial markets did not anticipate a significant economic impact until this time. In retrospect, this seems surprising, because China placed 11 million people in Wuhan under lockdown on January 23, and reports on cases outside of China emerged already in late January. However, this is in line with the reactions (or lack thereof) by health authorities in many countries, which largely ignored several warnings issued by the World Health Organization in January. This resulted in missed opportunities to stock up on face masks and disinfectants and losing valuable time in preparing hospitals and nursing homes for the pandemic.

After first smaller movements on February 21, essentially the same pattern of changes can be observed across markets on February 24. The trigger for that seems to have been

\(^1\)https://alwe.shinyapps.io/risknd/
Figure 2: Risk-neutral densities estimated from equity index options: S&P 500 (top) and FTSE MIB (bottom), RNDs from February 24 (left) and March 16 (right).
Italy’s decision to place almost 50,000 people in the Lombardy region under lockdown. For all four maturities from 3M to 2Y, the width of the RNDs increases (implied volatilities go up) and probability mass is shifted to the left. Short-term options are more strongly affected, while longer-term options react relatively moderately. The following three weeks see further increases in implied volatilities across all maturities, coupled with a marked shift of implied densities to the left as indices fall sharply. The shape of the RNDs changes from almost symmetric and close to bell-shaped (before the crisis) to clearly asymmetric and much less peaked in mid-March. Market reactions until mid-March are still quite similar, but there are already first signs of the Italian market to be more severely affected.² From the second half of March onwards, however, the development of RNDs differs more across both markets and maturities. This can also be seen from Figure 3, which shows the deviations of the 5/50/95 percentiles of both 3M- and 24M-RNDs on the respective day from the index value as of February 20, 2020. This reference day is chosen as the last day before any reactions by the markets become visible in RNDs. The difference between time t quantiles and the index value on the reference day reflects both the shift to the left of the RNDs due to marked drops in index values and their widening due to the increase in risk. From mid-March onwards, the difference is highest for Italy, which has been hit by the pandemic earlier than other countries. For most of March and April, the 3M-RNDs for Japan and the US show the highest (relative) optimism, followed by Germany and the UK. France and Italy show the weakest short-term outlook. For the continental European countries and Japan, this is largely in line with the degree to which these countries have been affected by the pandemic in terms of cases and deaths. The UK’s RNDs during April and May are comparable to

²Ramelli and Wagner (2020) distinguish three periods in the early phase of the pandemic based on events such as lockdowns. They call the period from February 24 to March 20 “Fever”. Our RNDs support their classification. Using three different measures, Baker et al. (2020) also document a sharp increase in economic uncertainty in the US in March 2020.
those for the German market, despite overtaking Italy in the number of deaths by the end of May and still showing the steepest increase in deaths among all six countries by the end of May. For the US, the health figures are mixed, showing the highest number of cases and the steepest increase for this curve by the end of May, but much lower deaths than the UK, Italy and France. Despite the high number of COVID-19 cases, the US 3M-RNDs show the smallest impact among all 6 countries for most of the time. After lagging behind Japan in the 3M-outlook in March, however, the US market quickly catches up and ranks at the top, together with Japan, during April and May.

24M-quantiles in Figure 3 (right) show a largely similar picture: Japan and the US are viewed most optimistically by the markets, followed by Germany and the UK. France lags behind these countries in terms of the median. While its 5% quantile is comparable to the top group, its 95% quantile is markedly lower, indicating less upward potential even in optimistic scenarios. Italy clearly shows the most difficult prospects also at the 24M horizon, with a clear gap to the rest for all quantiles shown. This is in line with the findings of Gerding et al. (2020), who note that a country’s fiscal capacity is a major determinant of

Figure 3: Deviation of 5/50/95-quantiles of 3M- (left) and 24M-RNDs (right) between Jan. 1 and May 25, 2020 from index value as of February 20, 2020.
economic losses due to rare disasters.

5. Conclusion and Outlook

Risk-neutral densities extracted from options on six stock indices show that financial markets did not anticipate major economic effects of the COVID-19 pandemic until late February. Market expectations reflected in these RNDs show rather similar behavior until mid-March, but diverge from this time onwards. Health statistics such as the number of cases and deaths in a country seem to have some effect: stock markets in countries with lower mortality (Japan, Germany, and the US) are viewed more optimistically than those with higher mortality (France, Italy). The exception to this is the UK, which shows a relatively optimistic outlook despite a high death toll. Interesting next steps are to estimate risk aversion during the first phase of the pandemic from RNDs, and to extend our analysis to GDP forecasts in the spirit of Gormsen and Koijen (2020), but with the added benefit of complete densities instead of point estimates.

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