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The impact of COVID-19 on tail risk: Evidence from Nifty index options

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A B S T R A C T

We investigate the impact of COVID-19 using multiple forward-looking measures of uncertainty in Indian stock markets using liquid Nifty index options. The WHO declaration of COVID-19 as a pandemic coincides with a sharp rise in all measures of uncertainty considered, including option-implied volatility smiles, risk-neutral density, skewness, and kurtosis. We find that while subsequent government-imposed lockdowns and monetary easing induced a near-normalization of skewness and kurtosis, the volatility level remained elevated, demonstrating the importance of higher moments in capturing uncertainty during a pandemic. Structural breaks identified using the Bai–Perron methodology closely track the dates of significant announcements or interventions.

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1. Introduction

COVID-19 has been characterized as an “uncertainty pandemic” (Rogoff, 2020). While vast literature documents the response of financial markets in March 2020 and as the pandemic spread, most of the existing studies study either market-wide returns (Choi, 2020) or sector-wise performance (He et al., 2020) and do not explore the pandemic’s impact on overall uncertainty and the tail risk. Using data from liquid Indian Nifty index options and futures contracts, we add to the stream of COVID-19 research by measuring its impact on market-wide uncertainty and tail risk implied by options markets. In particular, we document changes in the time series of daily volatility smiles, risk-neutral density (RND), and the skewness/kurtosis of Nifty returns’ distribution as COVID-19 spread in India after January 2020.

Complementing Topcu and Gulal (2020), who study returns on emerging stock markets around COVID-19, we quantify the uncertainty posed by COVID-19 through the onset of the pandemic and ensuing government-imposed lockdowns, using information from the Nifty index options traded on India’s National Stock Exchange (NSE). Two reasons motivate us to use options prices. First, option prices contain forward-looking estimates about future uncertainty. Second, while stock prices per se convey views only on directional bets, the volatility smile estimated using option prices embeds views on asymmetric and nonlinear bets. We use forward-looking measures of “at-the-money” implied volatility (ATM), “risk reversal” (RR), and “butterfly” (BF) to describe the evolution of uncertainty through imposition and lifting of government lockdowns as COVID-19 gained a foothold in India. Using the fitted smile, we also extract the daily risk-neutral probability density function and use it to describe the varying response of the left and right tails during different sub-periods identified using formal statistical models from January to May 2020.

2. Data and estimation methodology

Our market-implied measures of uncertainty are based on data on Nifty index options traded at the NSE, which has consistently ranked among the largest options markets worldwide by both volume and the notional trade value (World Federation of Exchanges, 2018). The Nifty index option contract ranks first globally by trade volume. The simultaneous availability of liquid futures prices makes it particularly attractive among other emerging markets. The sample period is January 1 to May 31, 2020, the latest available data at the study’s commencement.

2.1. Measures of tail risk

Our first set of measures for quantifying uncertainty is based on the construction of popular trades based on implied volatilities

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(IVs), namely, ATM straddle, RR, and BF. Following Malz (2014), the associated IVs are as follows:

- $\sigma_{ATM}$ (ATM) defines the IV corresponding to the straddle with its $\Delta = 0$ or with the corresponding Call $\Delta = 0.5$ (Call $\Delta$ + Put $\Delta = 0$ implies Call $\Delta = 0.5$).
- $\sigma_{25,SR}$ (RR) calculated as $\sigma_{25,AC} - \sigma_{25,AP}$ reflects the relative difference of the view on the change in the slope of the smile.
- $\sigma_{25,BF}$ (BF) calculated as $0.5 \times (\sigma_{25,AC} + \sigma_{25,AP}) - \sigma_{ATM}$ reflects the relative differences of the view on the change in the curvature of the smile.

We extract ATM, RR, and BF from the fitted smile by modeling each day's IV as a function of $\Delta$ using a quadratic model: $IV = a\Delta^2 + b\Delta + c$. Leveraging the availability of matching futures quotes, we compute $\Delta$ using the Black (1976) model, which obviates estimating dividend yields. Jain et al. (2019) found that a quadratic smile provided a good fit to Nifty option prices. The evidence from properties of the fitted value of the three coefficients suggests a quadratic function with a marked skew (with $b \leq 0$ for more than 3/4th of the sample) but limited convexity (within the median value of $a$ being 0.13) can approximate the smile in Indian markets adequately.

The motivation for using all the components/attributes of the volatility smile for measuring the uncertainty in the tail is that it is different from the uncertainty about the middle of the distribution. Furthermore, the uncertainty about the two tails is also not the same, particularly relevant during a period like the pandemic when the risks of extreme outcomes are more salient. In their cross-country study on modeling information diffusion during COVID, Arteaga-Garavito et al. (2020) found that the countries more exposed to COVID exhibited higher negative skewness in their returns' distribution. In contrast, this study explicitly quantifies the left- and right-tail probabilities during different stages of COVID spread in India.

2.2. Risk-neutral density (RND)

Breeden and Litzenberger (1978) showed that the model-free risk-neutral probability density could be extracted from option prices. We use a quasi-analytical approach recently developed by Hayashi (2020) to compute both the density and the tails (cumulative distribution function).

3. Results and discussion

We first present the variations in ATM, RR, and BF for the Nifty options through the sample. Since options markets are forward-looking, we hypothesize that the measures used would allow us to capture the change in uncertainty from the beginning of the disease’s spread to periods of lockdowns and policy interventions in India. We identify any changes in their behavior using the Bai and Perron (2003) approach, which allows us to measure the structural breaks endogenously.

Fig. 1 plots the time series of ATM, RR, and BF along with the breakpoints (vertical dotted lines) identified by the Bai and Perron method. We set the segment size at 15% of the sample size and a cap of a maximum of three breakpoints to identify the breakpoints. The horizontal dotted lines with cross marks at the end show the confidence intervals (Bai, 1997). While confidence intervals for BF and RR are relatively wider than those for ATM, the dates for structural breaks are within two trading days across all three.

The identified breaks for all three smile attributes are closely connected to important COVID-19-related events/announcements. In particular, we notice an upward trend in the (absolute) value of all three series after the Italy lockdown (February 23), before which COVID-19 was perceived as being confined to China.

The first structural break in ATM and RR coincides with the WHO announcement of COVID-19 as a global pandemic (March 11, 2020). The plot shows that while ATM remained elevated until late April 2020, BF and RR subsided soon after the Indian government enforced a complete three-week lockdown (March 24, 2020), and RBI, the Indian central bank, announced aggressive credit/liquidity interventions (March 27, 2020). The second break occurred around the policy intervention dates, while the third break occurred during subsequent phases of progressively milder lockdowns in India (April 14, May 3, and May 17, 2020). On May 12, the Indian government announced a 20-trillion INR stimulus package, after which the ATM levels appear to have subsided to the levels observed before March 2020.

3.1. RND and tail probabilities

Next, we turn our attention to RND and tail probabilities implied by the fitted volatility smile. There is a separate RND for each day, whose domain (strike levels) differ. To make the comparison of the implied RND tractable, we compare densities and tail probabilities only on the important days (Hanke et al., 2020) around the identified structural breaks — in particular, March 11, March 27, and April 15, 2020. We also include January 1, a date much before COVID-19 gained a foothold, for comparison purposes.

Fig. 2 shows that as the concerns about the COVID-19 pandemic grew in late February and early March, the RND shifted leftward as the Indian markets plunged downward along with other emerging markets (Topcu and Gulal, 2020). By late March, as the situation’s gravity became clearer, the density shifted further backward and the distribution’s width became wider, signifying an increase in both ATM volatility and its convexity. Both the tails increased in magnitude, signifying an increase in both downside and upside uncertainties. More importantly, the small pre-crisis left skew increased dramatically, which has also been observed from other liquid options markets (Hanke et al., 2020) and cross-country studies (Arteaga-Garavito et al., 2020).

The tails are more clearly visible in Fig. 3. Here, we follow the standard practice of considering multiplicatively symmetric price rises and declines. A 25% change denotes a futures level of $F \times 1.25$ on the upside and $F \div 1.25$ on the downside (a 20% decline). Before the crisis, a change of 25% in either direction had a negligible probability (less than $10^{-8}$). By mid-March, when WHO had just declared COVID-19 a global pandemic, the probability of the index declining by at least 25% was around 1.5%, while the probability of the index rising by at least 25% was only around 0.01%. This indicates that, at this level, the left tail was more than 100 times fatter than the right tail (if we considered additively symmetric changes, the disparity in the tails would be even worse). By late March, the tails had become about eight times fatter than they were two weeks earlier (a 25% decline had a 13% probability). By late April, the tails had reverted to roughly early/mid-March levels.

The evidence on the shift in RNDs is robust to the smile computed with respect to the delta or different measures of moneyness (results available on request), with the choice to present it in terms of delta driven by its popularity in the options market and recent literature (Malz, 2014; Hayashi, 2020).

4. Conclusions

We find that COVID-19 caused a dramatic shift in the first four moments of the risk-neutral distribution of the future stock market index. The RND shifted to the left (mean shift) and became...
wider (variance increase). There was a substantial fattening of the left and right tails, signifying an increase in both downside and upside uncertainties (kurtosis increase). More importantly, the small pre-crisis left skew increased dramatically (increase in the negative skewness). The government’s policy response ameliorated the skewness and kurtosis shifts reasonably quickly, but the variance remained elevated for much longer. This indicates a rational market assessment that the rescue package had suppressed the extreme tail risks but had not by any means extinguished the higher uncertainty caused by the pandemic. Before the WHO declared COVID-19 a pandemic, our results show a gradual buildup of uncertainty (both mid-distribution and tails) after the Italian lockdown of late February when there had not been a single COVID-19 death in India, and the number of cases was in single digits.

Our study has demonstrated the advantages of working with forward-looking measures of uncertainty derived from the options markets. It contributes to the growing COVID-19-related literature by demonstrating that unidimensional measures of uncertainties are inadequate to capture the multifaceted impact of an event like a pandemic. The methodology used in the paper can also be applied in other global markets with a liquid options market.
Fig. 3. Comparison of tail probabilities for Nifty over key dates.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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