

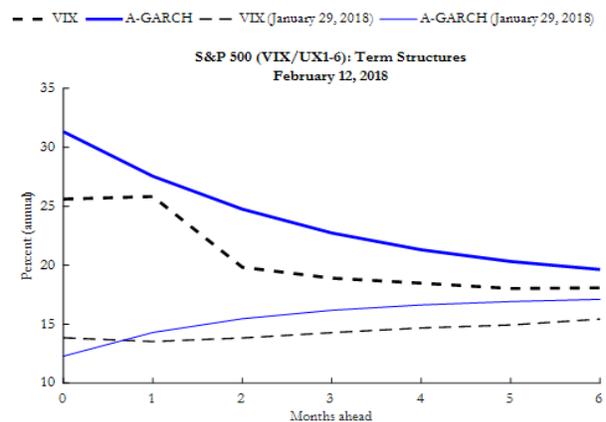
ONLINE ANNEX 1.1. OPTION-IMPLIED VOLATILITY: THE QUANTITY AND PRICE OF RISK FOR STOCKS AND BONDS¹

A key question in the aftermath of the VIX (Chicago Board Options Exchange Volatility Index) tantrum in early February, as well as amid investors' concerns in late March about an escalation in protectionist measures, is whether investors are now more reluctant to sell volatility. Some evidence from an asset-pricing perspective, rather than information about investor positioning and flows, suggests otherwise. Instead, market participants' willingness to bear volatility risk rebounded soon after the initial shock in February and remains robust, which is broadly consistent with accommodative financial conditions. To make this determination, note that option-implied volatility encompasses information not only about investors' expectations of volatility over the life of an option, but also about the compensation they require to incur the risks around those projections. Therefore, in principle, the sharp increase in the VIX and other equity option prices in early February could be the result of some combination of increases in the perceived quantity of risk, on the one hand, and increases in its price, the so-called variance risk premium (VRP), on the other.

As in the discussion in the main text regarding the conditional price of underlying risky assets (for example, sovereign bonds), this distinction matters. An increase in the VIX that reflects mainly a rise in expected volatility rather than a greater price of risk would be more consistent with persistently accommodative financial conditions, insofar as investors do not require more compensation to bear uncertainty. Conversely, the extent to which a VIX increase can instead be traced to greater VRPs rather than forecasts of higher volatility would reflect more worrisome tightening in financial conditions.

To appropriately assess the sharp increase in the VIX in early February, the critical question is the extent to which the change in the VIX comprises higher volatility forecasts as opposed to greater VRPs. To this end, the key ingredient is the forecast of volatility over the horizon of the option(s). The dashed black lines in Online Annex Figure 1.1.1 trace out the VIX futures term structure through six months ahead for two dates in 2018 that bracket the VIX tantrum, January 29 and February 12. The solid blue lines show the corresponding asymmetric, generalized autoregressive conditional heteroscedasticity-based (A-GARCH-based) six-month forecast of

Online Annex Figure 1.1.1. VIX Implied Volatility and A-GARCH Forecast Term Structures



Source: IMF staff estimates based on market quotes from Bloomberg. Note: Initial A-GARCH estimate sample: October 24, 2006–November 30, 2010. A-GARCH = asymmetric, generalized autoregressive conditional heteroscedasticity; VIX = Chicago Board Options Exchange Volatility Index.

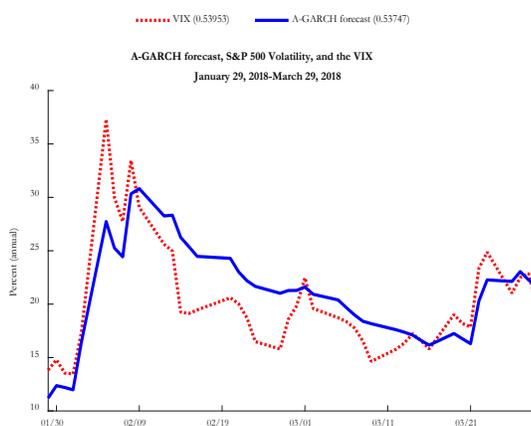
¹Real-time estimates with expanding four-year window.

¹ This is an annex to Chapter 1 of the April 2018 *Global Financial Stability Report*. © 2018 International Monetary Fund.

volatility, which notably allows volatility to increase when asset returns are negative. The upward move in the dashed black lines conveys the net revision in the VIX futures term structure over that period, which went from a modestly upward sloping to an inverted shape. A similar move is evident with respect to the forecasts (the solid lines). However, given that the forecast trajectory (solid line) lies above VIX futures quotes (dotted line), this approach seems to suggest that the increase in the VIX reflected a perceived greater quantity of risk rather than a notably higher price of risk over the episode. In turn, a low VRP is broadly consistent with accommodative financial conditions.

Two caveats are important. First, Online Annex Figure 1.1.1 references net changes in closing quotes during a fairly turbulent period. Intraday VIX quotes were highly volatile, amid heavy losses among volatility short sellers who had to cover their positions, and the VRP may have spiked during these periods. Even so, the net change suggests that such episodes were short-lived. Indeed, consider Online Annex Figure 1.1.2, which shows the VIX and the corresponding forecast of equity market volatility through the end of February and the period of concern about global protectionism in late March. As the gap between the two series suggests, options prices fell back in line with volatility forecasts by the end of the week of the VIX tantrum. Moreover, the VRP risk premium was often negative for the remainder of February and near zero in late March, which suggests that plenty of investors were willing to sell volatility again in short order after the initial spike.

Online Annex Figure 1.1.2. The VIX and Corresponding GARCH Forecast



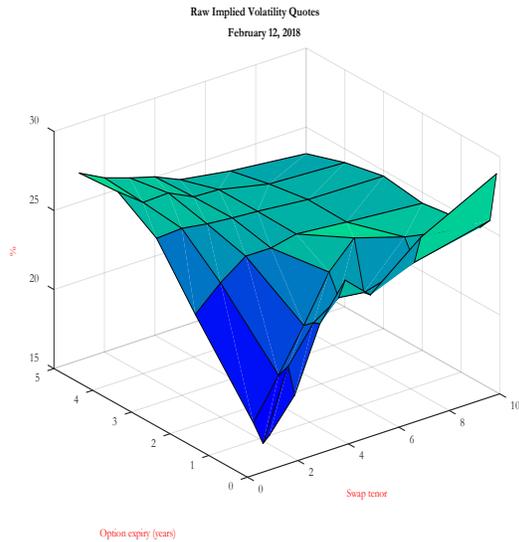
Source: : IMF staff estimates based on market quotes from Bloomberg. Note: Z-scores are in parentheses. The A-GARCH forecast is based on an expanding window with 18 years minimum beginning January 5, 1970. Sample average (latest value) of estimated variance risk premium = 2.73 (–0.02). Z-score of latest variance risk premium = –0.74. A-GARCH = asymmetric, generalized autoregressive conditional heteroscedasticity; VIX = Chicago Board Options Exchange Volatility Index.

Second, the VRP itself is an unconditional estimate of the price of risk. Similar to the discussion of term premiums (see Box 1.2), other factors, in turn, might affect the price of risk, perhaps including the volatility of volatility itself, which this simple analysis omits. In other words, this analysis of the VRP does not answer the question of whether the price of risk is “too high” or “too low” relative to fundamentals.

Of course, the same framework is applicable to implied volatility of other assets, including interest rates. For example, Online Annex Figure 1.1.3 shows implied volatility quotes on February 12 for the so-called at-the-money swaptions cube (the vertical y-axis), with tenors (the right x-axis) ranging from 1 to 10 years and option expirations ranging from three months to five years (left x-axis).

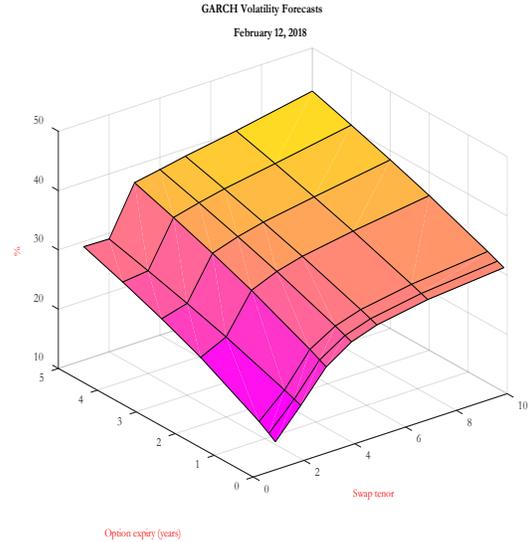
Akin to the previous consideration of the VIX futures term structure, Online Annex Figure 1.1.4 shows the GARCH-based forecasts of interest rate volatility on that date, again for each tenor and each option horizon.

Online Annex Figure 1.1.3. Swaption-Implied Volatility Quotes



Source: IMF staff estimates based on market quotes from Bloomberg.

Online Annex Figure 1.1.4. Swaption Volatility Forecasts



Source: IMF staff estimates based on market quotes from Bloomberg.

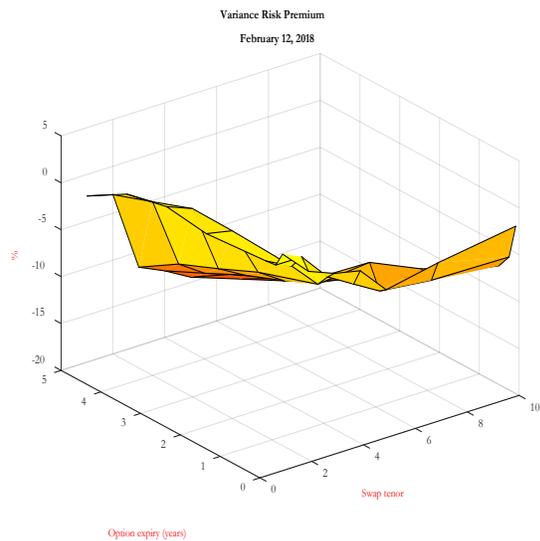
Note: GARCH = generalized autoregressive conditional heteroscedasticity.

Briefly, and to summarize across all points along these two surfaces, the volatility forecasts in Online Annex Figure 1.1.4 generally exceed the raw implied volatility quotes shown in Online Annex Figure 1.1.3. Indeed, the VRPs, the price of interest rate volatility, appeared to be negative shortly after the VIX tantrum, perhaps especially for longer-dated options on longer-dated maturity swaps, as Online Annex Figure 1.1.5 conveys.

Finally, these particular estimates of the VRP across the at-the-money swaptions cube remained subdued through the weeks following equity market tremors of early February, as Online Annex Figure 1.1.6 suggests.

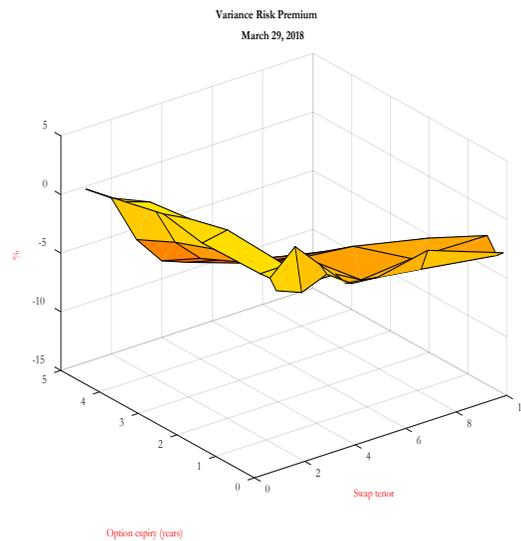
Similar caveats apply to the analyses of the VRP for swaptions; namely, that the gap between implied and forecast volatility could, in turn, reflect changes in other variables. However, and again on net, revisions in implied volatility across stocks and fixed-income instruments seem to reflect greater forecasts of volatility than sharp swings in sentiment to date.

Online Annex Figure 1.1.5. Swaption Variance Risk Premiums



Source: IMF staff estimates based on market quotes from Bloomberg.

Online Annex Figure 1.1.6. Swaption Variance Risk Premiums



Source: IMF staff estimates based on market quotes from Bloomberg.