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Variance swaps, non-normality and macroeconomic and financial risks

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ABSTRACT

This paper studies the determinants of the variance risk premium and discusses the hedging possibilities offered by variance swaps. We start by showing that the variance risk premium responds to changes in higher order moments of the distribution of market returns. But the uncertainty that determines the variance risk premium – the fear by investors to deviations from normality in returns – is also strongly related to a variety of macroeconomic and financial risks associated with default, employment growth, consumption growth, stock market and market illiquidity risks. We conclude that the variance risk premium reflects the market willingness to pay for hedging against these financial and macroeconomic sources of risk. An out-of-sample asset allocation exercise shows that the inclusion of the variance swap reduces the modified value-at-risk with respect to a portfolio holding exclusively the equity market portfolio.

1. Introduction

Why is the variance risk premium (*VRP* hereafter) reported to be negative, on average, for all available horizons? Since the payoff of a variance swap contract is the difference between the realized variance and the variance swap rate, negative returns to long positions on variance swap contracts for all time horizons mean that investors are willing to accept negative returns for purchasing realized variance.[1] Equivalently, investors who are sellers of variance and are providing insurance to the market, require substantial positive returns. This may be rational, since the correlation between volatility shocks and market returns is known to be strongly negative and investors want protection against stock market crashes. However, this intuition does not explain the large average negative variance risk premium observed at all horizons. In order to be more precise about our understanding of the negative magnitude of the variance risk premium, this paper identifies the main aggregate risks that variance swaps may hedge.

We formally investigate the hedging ability of variance swaps against a variety of financial and macroeconomic risks. The first contribution of this paper is to show that going long in a variance swap allows the investor to hedge not only equity market risk, but also default risk, aggregate consumption risk, and market-wide illiquidity risk. Additionally, this hedging ability depends on the investment horizon. It is important to notice that our objective is not to perform a horse race among available instruments to check whether the variance swap is more effective in covering business cycle and financial risks than potential competitors. Specifically, we do not compare the variance swap with default-based derivatives, individual variance swaps or with VIX call and put options. These alternative instruments may be playing a similar role than variance swaps. This paper focuses on analyzing the risks that the variance swaps actually hedge in order to understand better the large negative variance risk premium reported in literature.

The aim of the second part of the paper is to understand why variance swaps are able to hedge risks embedded in variables other than equity market returns. For this purpose we follow the model proposed by Chabi-Yo (2012) that theoretically determines the variance risk premium in terms of higher order moments of the conditional return distribution over and above the mean and variance of the stock market portfolio. Our estimates of that model

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[1] In this paper, we analyze the variance swap contract on the S&P500, and not stock variance swaps on individual assets. A variance swap is an OTC derivative contract in which two parties agree to buy or sell the realized volatility of an index or single stock on a future date. Whenever we mention a variance swap or a variance risk premium, we refer to just variance swaps on the equity market portfolio. For empirical evidence about the negative variance risk premium on the S&P500 index, see Carr and Wu (2009) and the papers cited in their work.

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indicate that, for maturities up to 6 months, the VRP is mainly determined by kurtosis. For the 12-month horizon, investors also fear that skewness contributes to the distance between the physical and risk-neutral volatilities. In addition, we also analyze the relation between these higher moments of equity returns and standard macroeconomic and financial variables measuring aggregate risks. Our results suggest that kurtosis, characterizing the market portfolio return, is positively and significantly related to the time-series behavior of the dividend-price ratio, default risk, aggregate consumption growth, and market-wide illiquidity risk. This finding may explain the ability of the variance swap for hedging the risk associated to these financial and macroeconomic risk factors. Additionally, the capacity of the variance swap for hedging against market risk at all horizons, the price-dividend risk at the 1-month horizon, and default risk at the 6-month horizon may also be associated with the relation between these variables and the skewness of returns.

Since our analysis suggests that variance swaps may be effective in covering the risk of extreme bust events in returns, we finally investigate the benefits of adding to the equity market portfolio a long position in the variance swap. We find that the modified value-at-risk of the portfolio decreases due to the inclusion of the volatility exposure.

This paper is organized as follows: Section 2 briefly describes the variance swap contract and defines the variance risk premium, while Section 3 contains a description of the data. The hedging ability of the variance risk premium against a variety of financial and economic risks is reported in Section 4. The determinants of the variance risk premium and their relationship to several financial and economic risks are discussed in Section 5. Section 6 provides two robustness tests. The first one considers estimating realized variance using daily returns, rather than intra-daily returns. The second one employs an extended sample period. Section 7 analyzes the benefits of including an exposure to variance into an equity portfolio and, finally, Section 8 concludes with a summary of our findings.

2. Variance swap contracts and the variance risk premium

A variance swap is an over-the-counter financial instrument that pays the difference between a standard estimate of the realized variance of the return on a given asset and the fixed variance swap rate. One leg of the variance swap pays an amount based upon the realized variance of daily log returns over the life of the contract, $RV_{t,t+\tau}$, computed with the commonly used closing price of the underlying asset. The other leg of the swap pays a fixed amount, the strike or variance swap rate, $SW_{t,t+\tau}$, quoted at the deal's inception. Thus the net payoff to the counterparties is the difference between these two values. It is settled in cash at the expiration of the deal, though some cash payments are likely to be made along the way by one or the other counterparty to maintain an agreed upon margin. The payoff of a variance swap with maturity at $t+\tau$ is therefore given by,

$$N_{var}(RV_{t,t+\tau} - SW_{t,t+\tau}), \tag{1}$$

where N_{var} denotes variance notional.

Since variance swaps cost zero at entry, for no arbitrage opportunities to exist the variance swap rate must be equal to the risk-neutral expected value of the realized variance,

$$SW_{t,t+\tau} = E_t^Q(RV_{t,t+\tau}), \tag{2}$$

where $E_t^Q(\cdot)$ is the time-t conditional expectation operator under some risk-neutral measure Q. The variance risk premium at period t is then defined as,

$$VRP_{t,t+\tau} = E_t^P(RV_{t,t+\tau}) - SW_{t,t+\tau}, \tag{3}$$

where $E_t^P(\cdot)$ is the time-t conditional expectation operator under the physical probability measure P. If investors price variance risk, the variance swap rate will differ from the expected realized variance under P at the corresponding horizon, the difference being the variance risk premium.

3. Data and descriptive statistics

In this paper we analyze variance swap contracts on the S&P 500 index for five alternative horizons: $\tau = 1$, 2, 3, 6, and 12 months. The midpoint of bid and ask quotes at the closing of the day for variance swap rates from January 4, 1996 to January 31, 2007 were obtained from the Bank of America.[2] We get monthly data by using the mid-quotes on the last day of each month.[3]

Our estimation of realized variance uses intra-daily returns on the S&P 500 index observed at 30-min intervals, from 9 a.m. to 3 p.m.,[4] Central Standard Time zone, with data provided by the Institute of Financial Markets. For each month t in our sample, we compute the realized variance for each maturity τ of a variance swap contract ($\tau = 1$, 2, 3, 6, and 12 months). Let R_{t+j} be the S&P500 log-return over the 30-min interval between $t+j-1$ and $t+j$, and let N^τ be the number of 30-min periods in the interval $(t, t+\tau)$.[5] Then, realized variance from t to $t+\tau$ is estimated as:

$$RV_{t,t+\tau} = \frac{1}{\tau}\sum_{j=1}^{N^\tau}(R_{t+j} - \bar{R}_{N^\tau})^2, \tag{4}$$

where $\bar{R}_{N^\tau}$ is the average return over the 30-min periods in the interval from t to $t+\tau$. By dividing the sum of squared deviations by τ, the realized variance is given on a monthly basis independently of the horizon.

For each month t and each maturity τ, we estimate the variance risk premium, VRP, as the difference between the realized variance and the swap rate,

$$VRP_{t,t+\tau} = RV_{t,t+\tau} - SW_{t,t+\tau}. \tag{5}$$

Clearly, the variance risk premium is only known at time $t+\tau$, since the realized variance is only observed at the end of the swap contract.

Fig. 1 displays variance swap rates and realized variances for 1-, 3- and 6-month maturities. As expected, the swap rate is most often above the level of realized variance, especially for longer maturities. This evidence is similar to that shown by Carr and Wu (2009) for stock market indices and, to a lesser extent, for individual stocks.[6] It

[2] The availability of these data allows us to avoid the relatively complex calculations and large datasets needed to replicate the swap rates using calls and puts on the S&P500 index. See, among others, Carr and Wu (2009) for details of the estimation.

[3] It is usually accepted that the mid-quote is a good representative proxy of the fundamental value of the asset, which explains why is widely employed in literature. Regarding the transformation of the variance swap rates from daily data to a monthly frequency sample, we also consider the average rate over all days within each month. It turns out that the characteristics of both series are practically the same.

[4] There is a relatively large literature covering the high-frequency variance computation. A recent example discussing the estimation of the variance risk premium using high-frequency techniques is the paper by Bollerslev et al. (2010).

[5] Depending on the specific month and horizon, N^τ takes different values. On average, N^τ is 270 for $\tau = 1$ and 3244 for $\tau = 12$.

[6] Driessen et al. (2009) and Vilkov (2008) show that the variance risk premium for stock indices is systematically larger, i.e., more negative, than for individual