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Jump and variance risk premia in the S&P 500 ☆

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ABSTRACT

We analyze the risk premia embedded in the S&P 500 spot index and option markets. We use a long time-series of spot prices and a large panel of option prices to jointly estimate the diffusive stock risk premium, the price jump risk premium, the diffusive variance risk premium and the variance jump risk premium. The risk premia are statistically and economically significant and move over time. Investigating the economic drivers of the risk premia, we are able to explain up to 63% of these variations.

1. Introduction

It is well known that asset price processes exhibit both smooth and discontinuous components. A large literature, including Merton (1976), Heston (1993), Duffie et al. (2000), Eraker et al. (2003) and Eraker (2004), makes a compelling case for models of asset prices that include stochastic volatility as well as jumps in prices and variance. This paper aims to shed more light on the compensation that investors demand for their exposure to these risks.

We contribute to extant literature in two directions. First, we use a long time-series of spot data and a large panel of option prices to estimate a stochastic volatility model with contemporaneous jumps in returns and variance (SVCJ). We first apply the Markov Chain Monte Carlo (MCMC) algorithm to the time-series of spot returns in order to estimate the latent variance process and the parameters that govern the dynamics of the S&P 500 index returns under the physical measure ($\mathbb{P}$). We then use the calibrated instantaneous variance and our option data to extract the parameters under the risk-neutral measure ($\mathbb{Q}$). In performing our estimation, we are particularly careful to impose the theoretical restrictions discussed in Bates (2000) and Broadie et al. (2007).[1] We find strong evidence of stochastic volatility and jumps, raising questions as to whether these sources of risks are priced.

Second, we study the equity and variance risk premia embedded in the spot index and index option markets. We decompose the equity risk premium into the diffusive stock risk premium (*DSRP*) and the price jump risk premium (*PJRP*). Similarly, we dissect the variance risk premium into the diffusive variance risk premium (*DVRP*) and the variance jump risk premium (*VJRP*). Generally, we find that the equity and variance risk premia are

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[1] Bates (2000) and Broadie et al. (2007) stress that the volatility of the variance process, as well as the correlation between the Brownians of the price and variance process, should be consistent across both probability measures.

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mainly driven by the compensation for jumps. Our analysis reveals important variations in the time-series of the risk premia. Using a large dataset of macroeconomic forecasts, we construct empirical proxies of macroeconomic expectations and uncertainty. We complement these variables with the default spread (DFSPD), the term spread (TSPD) and Corwin and Schultz (2012)'s illiquidity proxy (ILLIQ). We regress the individual risk premia on these variables and obtain adjusted R^2 of up to 63%. Our analysis reveals that macroeconomic uncertainty has substantially more explanatory power than macroeconomic expectations, suggesting that time varying uncertainty has a first-order impact on the variations in the risk premia, and thus on asset prices.

Naturally, our parametric approach may be subject to model misspecification risk. Especially, one might wonder whether two jump components — one in the return process and one in the variance process — are indeed necessary or whether the model is overspecified. To assuage these concerns, we compare the SVCJ model to two other model specifications often employed in the literature, namely the simple stochastic volatility model (SV) and the stochastic volatility model with jumps in returns (SVJ). We use the deviance information criterion (DIC) and the root mean squared errors (RMSE) of option prices to compare the three models. This analysis shows that the SVCJ model outperforms its rivals, lending more credence to our modeling choice. We also consider alternative ways in obtaining the latent variance and show that our findings are robust to different approaches. Finally, we assess the explanatory power of the Baker and Wurgler (2006) sentiment index for the risk premia and show that sentiment has a significantly negative impact on the price jump risk premium.

Our study is linked to the financial modeling literature that seeks to capture the dynamics of asset prices in parsimonious models. Bates (1996), Bakshi et al. (1997), Chernov and Ghysels (2000), Eraker et al. (2003), Jones (2003), Eraker (2004) and Kaeck (2013), among others, propose and test different models that feature stochastic volatility, jumps in returns or jumps in both returns and variance. Overall, these studies document the presence of stochastic volatility and jumps in both the return and variance processes. Building on this literature, we estimate a popular continuous-time model, the SVCJ model, to jointly study the dynamics of the equity and variance risk premia.

Our paper also links with the literature on the variance risk premium. Carr and Wu (2009) and Driessen et al. (2009) investigate the market price of variance risk of short-maturity in the equity market. Amengual (2009), Egloff et al. (2010) and Amengual and Xiu (2014) explore the term-structure of variance risk premia. Similar to Todorov (2010) and Bollerslev and Todorov (2011), we show that jumps play an important role in the dynamics of the equity risk premium.

Our study also carries interesting implications for the literature that focuses on theoretical models of asset prices. For instance, our analysis indicates that the price jump risk premium is time-varying and makes up a large proportion of the equity risk premium. An upshot of this result is that jumps should be incorporated in theoretical models of asset prices. This is because, a model without jumps would counterfactually imply that all of the equity risk premium is due to the diffusive component of the return process.

The works of Pan (2002) and Broadie et al. (2007) are most closely related to our study. They analyze the equity and variance risk premia in the S&P 500 option market. These studies focus on the unconditional risk premia estimated using relatively short sample periods. We improve on these papers in several respects. First, we analyze a longer sample that includes the recent financial crisis period which started around the collapse of Lehman Brothers. Obtaining a longer sample period is important in order to draw robust inferences about the time-variations of risk premia.[2] Second, we decompose the equity and variance risk premia into their continuous and discontinuous components and explore their interconnections. Third, we study the economic drivers of the variations in the risk premia.

Finally, our work adds to the literature on option returns. Bondarenko (2003) reports that average put returns are too high to be reconciled with standard factor models such as the capital asset pricing model (CAPM). Coval and Shumway (2001), Bakshi and Kapadia (2003) and Bakshi and Kapadia (2003) show that simple volatility trades such as short straddles earn as much as 3% per week. We estimate the distinct components of the variance risk premium and connect them to the macroeconomy, thus offering a risk-based explanation for these large option returns.

The remainder of this paper proceeds as follows. Section 2 describes our dataset and empirical methodology. Section 3 discusses our parameter estimates and analyzes the risk premia. Section 4 investigates the economic drivers of the risk premia. Section 5 discusses our robustness checks. Finally, Section 6 concludes.

2. Data and methodology

This section presents our data and methodology. We begin by describing our spot and options dataset. We then outline the econometric methodology used to estimate the model parameters and associated risk premia.

2.1. Data

We obtain the price-series of the S&P 500 index for the period between April 1990 and December 2010 from Bloomberg. Table 1 provides descriptive statistics of the daily percentage returns. We can see that the mean daily percentage return is positive (0.026). The mean daily volatility is 1.167. The skewness of daily returns is small and negative (−0.185). However, the kurtosis (12.168) is fairly high, indicating (not surprisingly) that S&P 500 spot returns are not normally distributed. These summary statistics are suggestive of the presence of stochastic volatility and/or jumps in the stock index market.

Our dataset of S&P 500 futures options contains daily settlement prices for the period from April 1990 to December 2010. S&P 500 futures options trade on the Chicago Mercantile Exchange (CME) and follow a quarterly expiration cycle, i.e. they expire in March, June, September and December. We process the option dataset as follows. We discard all option contracts that mature in less than 8 days, since they are typically associated with infrequent trading. In a similar vein, we expunge all options with maturity greater than a year. We also discard all option prices that are lower than five times the minimum tick size of 0.01 index points. S&P 500 futures options are of the American type. Thus, we follow Trolle and Schwartz (2009) and convert the American option prices into European option prices using the approach of Barone-Adesi and Whaley (1987).

Table 2 summarizes our final options dataset. We present the number of observations organized by moneyness, defined as the ratio of the strike price over the underlying's price. We also split our options data into three maturity groups: short (less than 60 days), medium (60–180 days) and long (more than 180 days) maturity options. This table reveals that most of our dataset contains option contracts of maturity up to 180 days.

[2] In comparison to our long sample period (1990–2010), Pan (2002) covers the period ranging from 1989 to 1996.