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The world price of jump and volatility risk

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ABSTRACT

We study international integration of markets for jump and volatility risk, using index option data for the main global markets. To explain the cross-section of expected option returns we focus on return-based multi-factor models. For each market separately, we provide evidence that volatility and jump risk are priced risk factors. There is little evidence, however, of global unconditional pricing of these risks. We show that UK and US option markets have become increasingly interrelated, and using conditional pricing models generates some evidence of international pricing. Finally, the benefits of diversifying jump and volatility risk internationally are substantial, but declining.

1. Introduction

A large literature has analyzed local versus global pricing of stock market risk (see Karolyi and Stulz (2003) for a survey). For developed equity markets, most evidence points towards a high degree of integration. This paper analyzes international integration of markets for equity index options and international pricing of volatility and jump risk. There are several reasons why the degree of integration of option markets may differ from equity market integration and why this is an interesting topic to study. First of all, unlike equity markets, option markets are relatively young, with low trading volume in the 1980s and a tremendous increase in trading over the last 15 years. Secondly, it is by now well understood that index options cannot be perfectly hedged with the underlying index, generating market incompleteness. Moreover, index option prices reflect risk premia that are not directly present in equity markets, such as volatility and jump risk premia. Even when equity markets are highly integrated, markets for index options may be more segmented. Trading volatility and jump risk internationally – either directly by trading options, or indirectly by investing in hedge funds – could then entail important international diversification benefits. Third, while the option pricing literature has documented large volatility and jump risk premia with US data, little is known about whether this is compensation for local or global volatility and jump (or 'crash') risk, or whether these risks are even priced in other index option markets.

To analyze these questions, we consider a large cross-section of index option returns for each of the three main global markets: the US (S&P 500 index options), Europe (FTSE 100 index options) and Asia (Nikkei 225 index options). We focus on parsimonious linear factor models to explain these cross-sections of index option returns. We first show that the one-factor model (where only stock market risk matters) is strongly rejected in all three markets and that explicitly accounting for a local priced volatility and jump risk factor improves the cross-sectional fit of the factor models substantially. Second, we find little empirical support for unconditional international pricing of jump and volatility risk. Incorporating conditioning information makes the evidence of international pricing stronger, especially between the US and the UK. The conditional analysis also suggests that integration has increased over time. In line with these results, a study of optimal portfolio choice with index options reveals that the gains from diversifying jump and volatility risk internationally are large, but decreasing over time.

As a first contribution, we extend the international finance literature by investigating international integration of index option markets, which are relatively young, but have become very large over the last two decades. The second contribution is to the option pricing literature, where a variety of authors (e.g. Bakshi and Kapadia, 2003; Buraschi and Jackwerth, 2001; Coval and Shumway, 2001; Pan, 2002; Jones, 2006; Broadie et al., 2007) have shown that exposure to stock market risk is not sufficient to explain option returns and that some additional sources of risk seem to be priced,

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with volatility risk and jump risk as obvious candidates. This paper offers an extensive analysis of risk factors affecting option returns, both in an unconditional and a conditional asset pricing framework. Our findings about the pricing of jump and volatility risk also have important implications for pricing and asset allocation in equity markets and hedge funds. Recent work has demonstrated that hedge funds feature option-like risk-return characteristics (Fung and Hsieh, 1997; Mitchell and Pulvino, 2001; Agarwal and Naik, 2004) and in particular that variance risk constitutes a key priced risk factor that explains their performance (Bondarenko, 2004). We will show that the intuitive measure of volatility risk that we use in this paper is closely related to Bondarenko's measure, so that our empirical results about international pricing of volatility risk shed light on the extent to which hedge funds could obtain international diversification benefits. In a different strand of the literature, Ang et al. (2006b) find that volatility risk also matters for the cross-section of stock returns, while Harvey and Siddique (2000) emphasize the importance of conditional coskewness, to which our measure of jump risk can be related. Finally, our findings are also relevant for the literature on contagion and international financial crises (see Bekaert and Harvey (2003), Claessens and Forbes (2001), and Karolyi and Stulz (2003) for surveys). For example, we show that US and UK option returns are substantially more highly correlated in periods of high global volatility.

Our methodology and findings can be summarized as follows. As explained above, we study option returns. Analyzing option returns has a number of benefits. First, there is no need to specify a particular parametric option pricing model.[1] Second, the presence of other risk factors (volatility and jump risk) can easily be tested for. Finally, excess returns are intuitive to interpret and immediately highlight the economic significance of the results.

In a first step, an unconditional local asset pricing model is estimated with time-series of returns on S&P 500 index options, FTSE 100 index options and Nikkei 225 index options. For each market, we have a large cross-section of options, with several moneyness levels and maturities. In this country-by-country analysis we extend Coval and Shumway (2001) by explicitly incorporating a volatility and a jump risk factor, and Jones (2006) by studying European and Asian markets. At-the-money straddles and out-of-the-money puts constitute the economic factor-mimicking portfolios for volatility and jump risk factors, respectively. We validate this interpretation by linking these factors empirically to the quadratic and cubic contracts of Bakshi et al. (2003). The model is first estimated for the three individual markets and then for the pooled global market, attempting to uncover the existence of international risk factors. The local pricing results are as follows. In line with the results for the US, we find clear evidence that the one-factor model does not correctly describe expected option returns in the UK and Japan. Next, we show that for the US and UK the inclusion of our factor-mimicking portfolios for local volatility and jump risk considerably improves the cross-sectional fit, while this is not the case for Japan. In line with the option pricing literature, we find for both the US and UK a negative volatility risk premium and a positive jump risk premium. Turning to the results for the international unconditional pricing models, we provide clear evidence against international pricing of US, UK, and Japan equity index options. Especially for Japan there is no evidence that non-Japan risk factors help in explaining expected option returns. If we exclude Japan from the analysis, the performance of the international pricing model is considerably better, but still worse than the local models.

In a second step, we focus on conditional asset pricing models. Our main goal is to analyze whether allowing for time-variation in expected returns changes our findings on local versus international pricing of options. We first analyze cross-market correlations of option returns and find an upward trend for US–UK correlations, consistent with increased market integration. Turning to more high-frequency dynamics, US–UK correlations between straddle returns depend positively on a natural instrument for international turbulence, namely option-implied volatility.[2] The same is true for cross-country correlations between out-of-the-money put returns, where the instrument is the implied volatility skew, which can be interpreted as a forward-looking measure of crash-o-phobia (Rubinstein, 1994). We explore this idea more formally in the linear factor model by using both instruments to scale the respective factor returns. Interestingly, accounting for conditioning information in this way further decreases the pricing errors of the US/UK model towards the pricing errors of the local models. The full international model, which attempts to explain all three markets simultaneously, is still rejected. In sum, we find some evidence of conditional international pricing, but local factors also matter.

Finally, we show that international diversification of option-based investment strategies has large benefits, owing to both the large risk premia on jump and volatility risk across different markets and the relatively low cross-market correlations of these strategies. Consistent with our findings of increased cross-market correlations, these international diversification benefits decrease over time, but remain important. This result provides further support for the hypothesis of increased but imperfect integration of world markets for jump and volatility risk.

Section 2 introduces the model and empirical set-up that we use to study international integration of option markets. The datasets, summary statistics and tests of the one-factor model for option returns are described in Section 3. Section 4 analyzes country-specific option risk factors in unconditional models. The unconditional international analysis is presented in Section 5. Conditional results are reported in Section 6, for both local and international models. Section 7 studies international portfolio choice with option-based investment strategies. Concluding remarks follow in Section 8.

2. Model and empirical setup

We study the cross-section of index option returns in 3 markets and analyze to what extent volatility and jump risk are priced, both locally and internationally. Rather than imposing a particular option pricing model, we focus on parsimonious linear factor models, where expected option returns are explained by their exposure to some priced risk factors, namely volatility and jump risk. Obviously, we also include an equity return factor in the model.

We use the well-known two-pass regression methodology (see Cochrane (2001) for a review). In the first step we regress (for each option i) the time series $\{R_{it}\}_{t=1}^{T}$ of option returns in excess of the riskfree rate on the time series $\{Y_{kt}\}_{t=1}^{T}$ of factor portfolio returns, which generates factor betas and time-series α's:

$$R_{it} = \alpha_i + \sum_{k=1}^{K} \beta_{ikt-1} Y_{kt} + \varepsilon_{it}. \tag{1}$$

We first estimate a single time-series regression per option instead of the rolling-regression approach (Fama and MacBeth, 1973), thus imposing $\beta_{ikt-1} = \beta_{ik}$, $\forall t$. In Section 6 we allow for time-varying betas. In the second step, we perform the well-known cross-sectional regression in which average returns across options, $\widehat{E}[R_{it}]$, are regressed on their estimated factor betas $\hat{\beta}_{ik}$:

[1] This is the approach taken by Mo and Wu (2007), who estimate a parametric international option pricing model and find complementary results.

[2] Previous research has found that international equity correlations are high when there are large shocks to equity prices (see for example Karolyi and Stulz, 1996).