Journal of Financial Economics 117 (2015) 558–584

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

The risk premia embedded in index options ☆

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ARTICLE INFO

Article history:
Received 25 August 2014
Received in revised form
3 December 2014
Accepted 16 December 2014
Available online 12 June 2015

JEL classification:
C51
C52
G12

Keywords:
Option pricing
Risk premia
Jumps
Stochastic volatility
Return predictability
Risk aversion
Extreme events

ABSTRACT

We study the dynamic relation between market risks and risk premia using time series of index option surfaces. We find that priced left tail risk cannot be spanned by market volatility (and its components) and introduce a new tail factor. This tail factor has no incremental predictive power for future volatility and jump risks, beyond current and past volatility, but is critical in predicting future market equity and variance risk premia. Our findings suggest a wide wedge between the dynamics of market risks and their compensation, which typically displays a far more persistent reaction following market crises.

1. Introduction

Equity markets are subject to pronounced time variation in volatility as well as abrupt shifts, or jumps. Moreover, these risk features are related in intricate ways, inducing a complex equity return dynamics. Hence, the markets are incomplete, and derivative securities, written on the equity index, are non-redundant assets. This

☆ We are grateful to Bill Schwert (the editor), David Bates (the referee), and Snehal Banerjee, Geert Bekaert, Peter Carr, Anna Cieslak, Bjorn Eraker, Kay Giesecke, Ravi Jagannathan, Bryan Kelly [our discussant at the National Bureau of Economic Research (NBER) meeting], Robert Merton, Toby Moskowitz, Lasse Pedersen, Sergio Rebelo, Myron Scholes, Ivan Shaliastovich (our discussant in Montreal, Canada), Allan Timmermann, Jonathan Wright, and Liuren Wu, as well as seminar participants at Kellogg School of Management, Northwestern University, Duke University, the 'Montreal 2013 Econometrics Conference: Time Series and Financial Econometrics,' the 40th Annual Meeting of the Danish Econometric Society, Sandbjerg, Denmark, the European University Institute, Florence, Italy 2013 Workshop on 'Measuring and Modeling Financial Risk and High Frequency Data', the 2013 'International Conference in Financial Econometrics' at Shandong University, Jinan, China, the '40 Years after the Black-Scholes-Merton Model' conference at the Stern School of Business (October 2013), the NBER Asset Pricing Meeting at Stanford University (November 2013), Georgia Tech, Boston University, Stanford University, the Insight Award Conference, sponsored by AQR Capital Management, Greenwich, Connecticut (April 2014), the 2014 Annual Society for Financial Econometrics (SoFiE) Meeting, Toronto, Canada, the 2014 Australasian Econometric Society Meetings, Tasmania, Australia, the 2014 NBER Summer Institute Forecasting, and Empirical Methods Meeting, and the 2014 European Finance Association (EFA) meeting, Lugano, Switzerland, for helpful comments. Torben G. Andersen gratefully acknowledges support from CREATES, Center for Research in Econometric Analysis of Time Series (DNRF78), funded by the Danish National Research Foundation. Viktor Todorov's work was partially supported by National Science Foundation Grant SES-0957330.
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http://dx.doi.org/10.1016/j.jfineco.2015.06.005
0304-405X/

partially rationalizes the rapid expansion in the trading of contracts offering distinct exposures to volatility and jump risks. From an economic perspective, it suggests that derivatives data contain important information regarding the risk and risk pricing of the underlying asset. Recent evidence, exploiting parametric models, e.g., Christoffersen, Jacobs, and Ornthanalai (2012) and Santa-Clara and Yan (2010), or nonparametric techniques, e.g., Bollerslev and Todorov (2011), finds the pricing of jump risk, implied by option data, to account for a significant fraction of the equity risk premium.

Standard no-arbitrage and equilibrium-based asset pricing models imply a tight relation between the dynamics of the options and the underlying asset. This arises from the assumptions concerning the pricing of risk in the no-arbitrage setting and the endogenous pricing kernels implied by the equilibrium models. A prominent example is the illustrative double-jump model of Duffie, Pan, and Singleton (2000) in which the return volatility itself follows an affine jump diffusion. In this context, the entire option surface is governed by the evolution of market volatility, i.e., the dynamics of all options is driven by a single latent Markov (volatility) process.

Recent empirical evidence reveals, however, that the dynamics of the option surface is far more complex. For example, the term structure of the volatility index (VIX) shifts over time in a manner that is incompatible with the surface being driven by a single factor, see, e.g., Johnson (2012). Likewise, Bates (2000) shows that a two-factor stochastic volatility model for the risk-neutral market dynamics provides a significant improvement over a one-factor version. Moreover, Bollerslev and Todorov (2011) find that even the short-term option dynamics cannot be captured adequately by a single factor as the risk-neutral tails display independent variation relative to market volatility, thus driving a wedge between the dynamics of the option surface and the underlying asset prices.

The objective of our paper is to characterize the risk premia, implied by the large panel of Standard & Poor's (S&P) 500 index options, and its relation with the aggregate market risks in the economy. As discussed in Andersen, Fusari, and Todorov (2015), the option panel contains rich information both for the evolution of volatility and for jump risks and their pricing. Consequently, we let the option data speak for themselves in determining the risk premium dynamics and discriminating among alternative hypotheses regarding the source of variation in risk and risk pricing.

The standard no-arbitrage approach starts by estimating a parametric model for the evolution of the underlying asset price. Risk premia are introduced through a pricing kernel, which implies that risk compensation is obtained through parameter shifts. This ensures, conveniently, that the risk-neutral dynamics remains within the same parametric class entertained for the statistical measure. However, this approach tends to tie the equity market and option surface dynamics closely together. The equity risk premia are typically linear in volatility. In contrast, we find the options to display risk price variation that is largely unrelated to, and effectively unidentifiable from, the underlying asset prices alone.

This motivates our reverse approach of directly estimating a parametric model for the risk-neutral dynamics exclusively from option data along with no-arbitrage restrictions based on nonparametric model-free volatility measures constructed from high-frequency data on the underlying asset. In this manner, we avoid letting a (possibly misspecified) parametric structure for the $\mathbb{P}$-dynamics impact the identification of option risk premia. Our goal is to synthesize the option surface dynamics in a low-dimensional state vector without imposing ad hoc restrictions based on the actual return dynamics and then proceed to explore the risk premia dynamics by combining the extracted state vector with high- and low-frequency data on the equity index.

Following Andersen, Fusari, and Todorov (2015), we specify a general parametric model for the risk-neutral return dynamics that allows for a separate left tail jump factor to impact the volatility surface. Simultaneously, we include two distinct volatility factors and accommodate co-jumps between returns and volatility as well as return asymmetries induced by (negative) correlation between both diffusive and jump innovations. Moreover, we explore both Gaussian and double-exponential specifications for the jump distributions. As such, we incorporate all major features stressed in prior empirical option pricing studies and allow for various novel features. We model the tail factor as purely jump-driven, with one component jointly governed by the volatility jumps and another independent of spot volatility. This feature allows the jump intensity to escalate, through so-called cross-excitation of the jumps, in periods of crises when price and volatility jumps are prevalent, thus amplifying the response of the jump intensity to major (negative) market shocks. The extended model remains within the popular class of affine jump-diffusion models of Duffie, Pan, and Singleton (2000) and exemplifies the flexibility of such models for generating intricate, yet analytically tractable, dynamic interactions between volatility and jump risks.

Any tractable and parsimonious parametric model is bound to suffer from some degree of misspecification. What is crucial for our analysis, however, is to avoid systematic biases in representing the information embedded in the option panel. We do this by allowing for a flexible state vector driving different components of the conditional risk-neutral return distribution. Most important, by introducing the left tail factor, we capture systematic variation in the corresponding part of the option surface, which is missed by traditional model specifications. One can view the time series realizations of our novel tail factor as a succinct quantification of dynamic features not accommodated by existing parametric asset pricing models.

Relative to Andersen, Fusari, and Todorov (2015), the system is generalized to allow the left tail factor to enter directly into the spot volatility process. In addition, all three state variables could impact the jump intensities. Consequently, we can explicitly test for the presence of the tail factor in volatility, and we can gauge the significance of the different state variables in driving separately the positive and negative jump intensities. Inference for the general model is feasible through the approach developed