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Learning, confidence, and option prices

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ABSTRACT

The option-market evidence suggests that investors are concerned with large downward moves in equity prices, which occur once every one to two years in the data. This evidence is puzzling because there are no concurrent jumps in macroeconomic fundamentals. I estimate a confidence-risk model where agents use a constant gain specification to learn about the unobserved expected growth from the cross-section of signals. While consumption shocks are Gaussian, investors' uncertainty (confidence measure) is subject to jumps, which endogenously trigger jump risks in equity and option markets. The model provides a good fit to macroeconomic, equity, option, and forecast data.

1. Introduction

One of the central findings in option markets is that the deep out-of-the-money index put options are too expensive relative to standard models (see e.g. Rubinstein, 1994). This suggests that investors are willing to pay a sizeable premium to hedge against large downward movements in the underlying asset prices. These large moves in the asset markets drive the equity prices down and concurrent market volatilities up at frequencies of once one to two years in the data.[1] The jump evidence from option and equity markets is puzzling from the perspective of economic models. There is no persuasive support for large contemporaneous moves in the real economy at the considered frequencies in the data, which presents a challenge for an economic explanation of jump risks in financial markets.[2]

In this paper, I show that there is a significant link in the data between option prices, equity price jumps, and the confidence of investors, measured from the cross-sectional variation in the forecasts about future macroeconomic growth. Drops in investors' confidence (high cross-sectional uncertainty) are associated, on average, with negative moves in market returns and significant increases in current and future implied volatilities in the option markets. Motivated by this evidence, I set up and estimate a structural model for the asset prices which can explain the observed link between the confidence measure and the variation in option prices and jumps in returns. In the model, there are no jumps hard-wired in the aggregate consumption and dividends processes, and the economic source of jump risks stems from sharp increases in investors' uncertainty regarding future growth. In the estimation, I find that the confidence risk model provides a good fit to the real consumption, equity, risk-free rate, the option-implied volatilities at difference strikes and maturities, and the expected growth and the confidence measure from the forecast data. The model can quantitatively explain asset-price anomalies in derivative markets and account for the observed large moves in returns at economically plausible preference and model parameters.

The economy setup follows the confidence risks model of Bansal and Shaliastovich (2009) and Bansal and Shaliastovich (2010). As in the long-run risks model of Bansal and Yaron (2004), the dynamics of the true consumption growth is conditionally Gaussian, and features a persistent expected growth component and a time-varying volatility of consumption shocks. However, unlike in a

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[1] Recent empirical work highlighting jumps in prices includes Bakshi et al. (1997), Pan (2002), Andersen et al. (2002), Eraker et al. (2003), Eraker (2004), Broadie et al. (2007), Santa-Clara and Yan (2010). For a nonparametric analysis of high-frequency data, refer also to Barndorff-Nielsen and Shephard (2006), Andersen et al. (2003) and Ait-Sahalia and Jacod (2012).

[2] This paper focuses on relatively frequent, once every one or two year large moves in equity markets, which are different from very large rare disasters considered in Barro (2006) and Rietz (1988).

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standard model, expected growth is not directly observable, and investors form an estimate of future growth using a cross-section of signals. The time-varying precision of signals determines the uncertainty of investors about their estimate of expected growth. To help distinguish this uncertainty from other measures in the literature, I refer to it as "the confidence measure". The confidence measure fluctuates over time, and is subject to positive Poisson jumps.

To model learning from the signals, I assume that the agents assign a constant weight to the recent information. Constant gain specification is considerably more tractable than the fully Bayesian specification, and has been used in a variety of economic studies. It can be justified in the environment with possible structural breaks at unknown dates. Alternatively, a constant gain specification is consistent with the recency bias evidence in the behavioral literature. This recency bias evidence in Hogarth and Einhorn (1992), De Bondt and Thaler (1990), and Kahneman and Tversky (1973) suggests that the agents have a tendency to over-weight recent information and under-weight less salient data such as long-term averages. De Bondt and Thaler (1990) further find that investors overweight recent information more in states of high uncertainty. The constant gain specification captures the intuition from these studies: the weight to the new information does not decrease with signal quality, as in the Bayesian approach, and therefore the agents over-weight the impact of recent information on their forecasts.

I solve the equilibrium model which features confidence jump risks and the constant gain/recency bias learning specification. In the model, investors demand risk compensation for consumption, expected growth, and consumption volatility risks. The novel aspect of the model is that the confidence risks are also priced in the equilibrium, so that when agents have a preference for early resolution of uncertainty, states with higher uncertainty about expected growth are discounted more heavily. Notably, the confidence jump shocks receive risk compensation even though there are no jump risks in consumption. Fluctuating confidence and confidence jumps can explain the option pricing puzzles and jump in returns. In equilibrium, positive jumps in the confidence measure translate into negative jumps in returns and positive jumps in the market volatility. Out-of-the-money put options hedge confidence jump risks and thus appear expensive relative to at-the-money options. This can account for the cross-section of option prices in the data, where Black–Scholes implied volatilities from options are decreasing in the moneyness of the contract. Further, endogenous jumps in equilibrium asset prices can account for the evidence of large downward moves and heavy-tailed unconditional distribution of equity returns in the data.

To show a direct evidence for the link between the confidence measure and asset prices, I use a cross-section of forecasts of real consumption from the Survey of Professional Forecasters and construct the empirical proxies for the average signal and the confidence measure in the data. Consistent with the theoretical model, the average signal corresponds to the average forecast in the data, while the confidence measure is computed from the cross-sectional variance in the forecasts, adjusted by the number of forecasts. The confidence measure contains significant information about option implied volatilities in the data. Its contemporaneous correlations with option variances range from 50% to 60% across the contracts, and it significantly predicts future implied variances 1 and 3 quarters ahead even controlling for the current value of the option variance. These findings supplement Bansal and Shaliastovich (2009) who show the evidence for a jump-like component in the confidence measure which is related to large moves in returns and return volatility.

I formally assess the quantitative fit of the model to the asset price, macroeconomic, and forecast data. My asset-price data consist of monthly real market returns, the market price–dividend ratios, the real interest rates, and the option-implied volatilities with moneyness ranging from 0.90 to 1.10 and with 1- and 3-month maturities. I use monthly observations of real consumption to measure aggregate growth, and I include quarterly expected growth and the confidence measure from the forecast data. The estimation exercise is quite challenging due to mixed frequency of observations, non-Gaussian dynamics of the latent states, and a non-linear relation between the data measurements and the economic states. To deal with these issues, I use a Bayesian MCMC, mixed frequency, particle filter estimation approach, which is most closely related to Schorfheide et al. (2013) and Song (2014). Johannes and Polson (2009) provide a handbook treatment of the Bayesian methods with applications in finance.

The quantitative results from the estimation provide empirical support for the confidence risks model. I obtain plausible preference parameters, which indicate that investors have a preference for early resolution of uncertainty. The median posterior estimate of the relative risk aversion is 10.7 and the intertemporal elasticity of substitution is 2.99. The estimated model parameters suggest that the confidence measure significantly fluctuates over time; moreover, nearly all the variation in the series is driven by Poisson jumps. Large moves in uncertainty about future growth translate to large negative jumps in equity returns. The estimated frequency of jumps in asset prices, driven endogenously by jumps in the confidence measure, is once every 2 months, and the average jump in returns is −2.5%, monthly. Even though the estimated jumps are quite frequent, many of them are quite small to lead to large detectable moves in equity returns. Both in the model and in the data, the probability of observing a large, two-standard deviation move in asset prices is about 4%, or once every two years.

In the model, the expected growth and the confidence risks contribute the most to the asset risk compensation. The compensation for the expected growth risks is about two-thirds of the market risk premium, while the confidence risks capture about a quarter of the equity risk premium, or 1.7%. As most of the confidence fluctuations are due to jumps, the confidence risk compensation thus captures the jump risk premium in the economy. These estimates of the jump risk premium are consistent with Pan (2002) and Broadie et al. (2007), who find that jump risks account for about one-third of the total equity risk premium.

The model with the confidence jump risks can quantitatively explain the cross-section of option prices and the variation in option-implied volatilities. Based on the median estimates, the unconditional at-the-money volatility is 18.1% in the model relative to 20.1% in the data (19.1% in the pre-crises sample). The difference between the out-of-the-money and at-the-money option volatilities is equal to 6.2% in the model relative to 6.7% in the data at a 1-month horizon, and it is 5.2% in the model and 5.6% in the data at a 3-month horizon. The in-sample root-mean squared errors range from 1.2% for at-the-money contracts to 2.8% for out-of-the-money contracts at 1 month to maturity. The confidence measure is the most significant driver of the variation in the out-of-the-money volatilities, while consumption volatility becomes more important for at- and in-the-money contracts.

Overall, confidence jumps play a significant role in explaining the cross-section of option prices. Without confidence jumps the model is unable to explain prices of the out-of-the-money option contracts, as the implied volatility curve is nearly flat across the strikes. I further consider an additional long-run volatility factor, as in Drechsler and Yaron (2011) and Bates (2012). While the addition of the factor improves the model fit to the option data, still it cannot substitute confidence jumps to account for the option price patterns in the data.