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Explaining asset pricing puzzles associated with the 1987 market crash ☆

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ABSTRACT

The 1987 market crash was associated with a dramatic and permanent steepening of the implied volatility curve for equity index options, despite minimal changes in aggregate consumption. We explain these events within a general equilibrium framework in which expected endowment growth and economic uncertainty are subject to rare jumps. The arrival of a jump triggers the updating of agents' beliefs about the likelihood of future jumps, which produces a market crash and a permanent shift in option prices. Consumption and dividends remain smooth, and the model is consistent with salient features of individual stock options, equity returns, and interest rates.

1. Introduction

The 1987 stock market crash has generated many puzzles for financial economists. In spite of little change in observable macroeconomic fundamentals, market prices fell 20–25% and interest rates dropped about 1–2%. Moreover, the crash triggered a permanent shift in index option prices: Prior to the crash, implied 'volatility smiles' for index options were relatively flat. Since the crash, however, the Black-Scholes formula has been significantly underpricing short-maturity, deep out-of-the-money Standard and Poor's (S&P) 500 put options (Rubinstein, 1994; Bates, 2000). This feature, often referred to as the 'volatility smirk,' is demonstrated in Fig. 1, which shows the spread of both in-the-money (ITM) and out-of-the-money (OTM) implied volatilities relative to at-the-money (ATM) implied volatilities from

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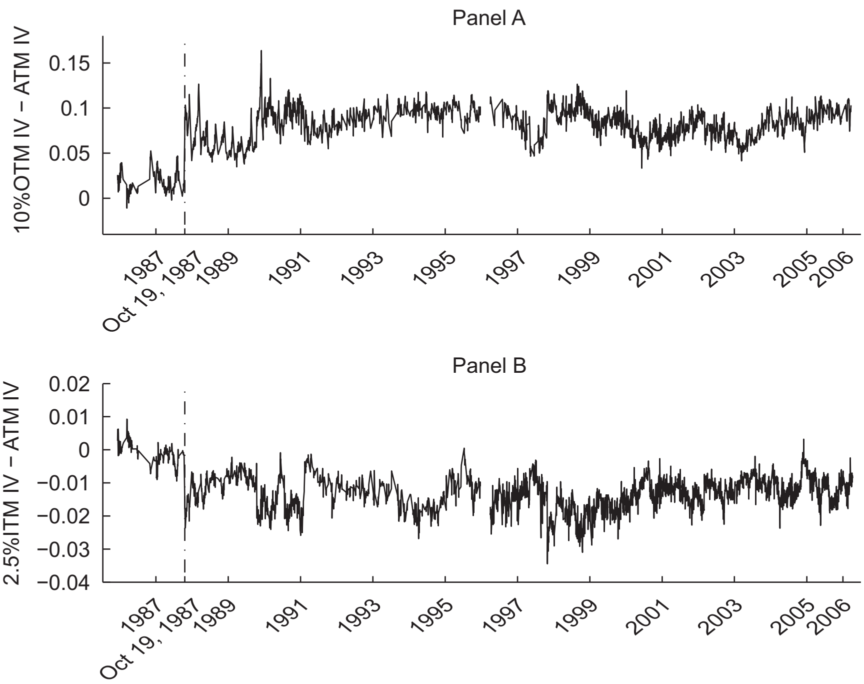

Fig. 1. Pre- and post-crash implied volatility smirk for S&P 500 options with one month to maturity. The plot in Panel A depicts the spread between implied volatilities for S&P 500 options with a strike-to-price ratio $X=K/S-1=-10\%$ and at-the-money implied volatilities. The plot in Panel B depicts the spread between implied volatilities for options with a strike-to-price ratio $X=K/S-1=2.5\%$ and at-the-money implied volatilities. Appendix D explains how we constructed the implied volatility series.

1985–2006. This figure clearly shows that the volatility smirk spiked upward immediately after the 1987 stock crash, and that this shift has remained ever since.

Not only is this volatility smirk puzzling in its own right, but it is also difficult to explain relative to the shape of implied volatility functions (IVF) for individual stock options, which are much flatter and more symmetric (see, e.g., Bollen and Whaley, 2004; Bakshi, Kapadia, and Madan, 2003; Dennis and Mayhew, 2002). Indeed, Bollen and Whaley (2004) argue that the difference in the implied volatility functions for options on individual firms and on the S&P 500 index cannot be explained by the differences in their underlying asset return distributions.

In this paper, we attempt to explain these puzzles while simultaneously capturing other salient features of asset prices. In particular, we examine a representative-agent general equilibrium endowment economy that can simultaneously explain:

- The prices of deep OTM put options for both individual stocks and the S&P 500 index.
- Why the slope of the implied volatility curve changed so dramatically after the crash.
- Why the regime shift in the volatility smirk has persisted for more than 20 years.
- How the market can crash with little change in observable macroeconomic variables.

We build on the long-run risk model of Bansal and Yaron (2004, BY), who show that if agents have a preference for early resolution of uncertainty, e.g., have Kreps and Porteus (1978)/Epstein and Zin (1989), or KPEZ, preferences with elasticity of intertemporal substitution $EIS > 1$, then persistent shocks to the expected growth rate and volatility of aggregate consumption will be associated with large risk premiums in equilibrium. Their model is able to explain a high equity premium, low interest rates, and low interest rate volatility while matching important features of aggregate consumption and dividend time series. We extend their model in two dimensions. First, we add a jump component to the shocks driving the expected consumption growth rate and consumption volatility. These jumps (typically downward for expected growth rates and upward for volatility) are bad news for the agent with KPEZ preferences, who will seek to reduce her position in risky assets. In equilibrium, this reduction in demand leads to asset prices exhibiting a downward jump, even though aggregate consumption and dividends are smooth. That is, in our model, the *level* of consumption and dividends follows a continuous process; it is their expected growth rates and volatilities that jump. Since shocks to expected consumption growth rate and consumption volatility are associated with large risk premiums, jumps in asset prices can be substantial, akin to market ‘crashes.’

Our second contribution relative to BY (2004) is to allow for parameter uncertainty and learning. Specifically, we assume the jump frequency is governed by a hidden two-state continuous Markov chain, which needs to be filtered in equilibrium. This adds another source of risk to the economy, namely the posterior probability of the