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Option pricing with stochastic liquidity risk: Theory and evidence[☆]

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Abstract

This study develops a liquidity-adjusted option pricing model that demonstrates the impact of the liquidity risk on stock prices using a liquidity discount factor. The discount factor relates to both mean-reversion stochastic market liquidity and the sensitivity of stock prices to market illiquidity. Our empirical results provide strong evidence in support of incorporating liquidity risk in options pricing. In particular, our model shows marked pricing improvement for out-of-the-money or longer term options, as well as options on stocks with lower levels of liquidity.

JEL classification: G13

Keywords: Option pricing; Liquidity risk; Liquidity discount factor

1. Introduction

A fundamental assumption underlying traditional option pricing models is that the underlying asset is perfectly liquid. In a real stock market, however, investors trade with liquidity risk. Many prior studies provide evidence that investors ask for illiquidity premium due to the liquidity risk (e.g., Amihud and Mendelson, 1991; Brennan and Subrahmanyam, 1996; Amihud, 2002;

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Pastor and Stambaugh, 2003; Acharya and Pedersen, 2005) and stocks with imperfect liquidity are priced at a liquidity discount compared to otherwise identical liquid stock (e.g., Siber, 1991; Brunetti and Caldarera, 2006). Consequently, the liquidity risk of the underlying asset directly affects option prices.[1]

Therefore, this study extends the specification of Brunetti and Caldarera (2006) on the dynamic process of the underlying asset based on stochastic market liquidity to develop a new option pricing model in which the underlying asset is not perfectly liquid. Our empirical results provide strong evidence that stochastic liquidity risk should be taken into consideration when pricing options. We show that an option pricing model that takes liquidity into account can substantially improve the pricing performance of the model that does not.

Our study is in line with recent studies on option pricing that do not assume that the underlying asset is perfectly liquid. Liu and Yong (2005) examine the effect of trading on the asset price to determine how liquidity risk within the underlying asset markets affects the replication of a European contingent claim. Cetin, Jarrow, Protter, and Warachka (2006) model liquidity risk based on the assumption that the supply curve of a stock is a function of the order flow. To measure varying liquidity costs, they implement an optimal hedging strategy to super-replicate an option. We follow Brunetti and Caldarera (2006), who incorporate the liquidity discount factor into the demand function of a stock to capture the impact of liquidity on stock prices. Prior literature (e.g., Jarrow, 2001; Subramanian and Jarrow, 2001; Longstaff, Mithal, and Neis, 2005), which demonstrates that the liquidity discount factor successfully captures the liquidity effect on the asset price, supports our adoption of this method.

We develop an option pricing model using a generalized specification of Brunetti and Caldarera's (2006) model to investigate the role of stock liquidity in option pricing performance. We assume that the liquidity discount factor is related to both market liquidity and the sensitivity of stock prices to market illiquidity, and relax the deterministic market liquidity process to allow a mean-reversion stochastic process.

Theoretically, our model differs from the existing approaches in at least two ways. First, in addition to developing a new option pricing model, we provide new insights into the ways in which liquidity is linked to option prices. In particular, we demonstrate the effect of the demand curve on stock prices. The demand curve is a function of the stock price and the liquidity discount factor, which distinguishes between the prices of a perfectly liquid stock and a corresponding, otherwise identical stock with imperfect liquidity. Second, we allow market liquidity to be a mean-reversion stochastic process and develop a new option pricing model using this generalized specification. The setting of the mean-reversion process is consistent with the dynamics of market liquidity proxied by alternative measures. In addition, unlike models that assume deterministic market liquidity, the adoption of the mean-reversion stochastic process in the estimation of market liquidity avoids overreliance on any particular liquidity measure. Researchers have yet to come to a general consensus on which type of liquidity is the most desirable. Indeed, Aitken and Comerton-Forde (2003) find that different studies using a variety of liquidity measures are likely to reach very different conclusions. Therefore, for model estimation to be more objective and consistent among studies, market liquidity must be stochastic.

Using a sample of Dow Jones Industrial Average (DJIA) component stocks, we compare our liquidity-adjusted (LA) model with a nonliquidity-adjusted (NLA) model. That is, we compare

[1]See the empirical studies such as Cetin, Jarrow, Protter, and Warachka (2006) and Chou, Chung, Hsiao, and Wang (2011).