North American Journal of Economics and Finance 33 (2015) 115–133

Contents lists available at ScienceDirect

North American Journal of Economics and Finance

State-dependent jump risks for American gold futures option pricing

Yu-Min Lian *, Szu-Lang Liao, Jun-Home Chen

Department of Money and Banking, National Chengchi University, No. 64, Section 2, Zhinan Road, Taipei, Taiwan

ARTICLE INFO

Article history:
Received 23 September 2014
Received in revised form 30 March 2015
Accepted 1 April 2015
Available online 15 April 2015

JEL classification:
C13
C15
G12
G13

Keywords:
State-dependent jump risk
American gold futures option
Merton measure
Esscher transform
Least-squares Monte Carlo method

ABSTRACT

In this study, we investigate the valuation of American-style options when the underlying gold futures price follows a pure diffusion structure with state-dependent jump dynamics. Under such dynamics, the jump events are described as a compound Poisson process with a log-normal jump amplitude, and the regime-switching arrival intensity is captured by a hidden Markov chain whose states represent the economic states. Considering the different jump risk assumptions, we use the Merton measure and Esscher transform to derive risk-neutral gold futures price dynamics under an incomplete market setting. To achieve a desired accuracy level, the least-squares Monte Carlo method is used to approximate the values of American gold futures options. Our empirical and numerical results based on actual market data are provided to illustrate the importance of incorporating state-dependent jump risks when pricing American put options on gold futures.

1. Introduction

Most exchange-traded option contracts are American-style, meaning that an investor has the right to exercise such options at any time before maturity. To address the early-exercise feature in

* Corresponding author. Tel.: +886 2 29393091x87141; fax: +886 2 29398004.
E-mail addresses: 95352506@nccu.edu.tw (Y.-M. Lian), liaosl@nccu.edu.tw (S.-L. Liao), 98352503@nccu.edu.tw (J.-H. Chen).

http://dx.doi.org/10.1016/j.najef.2015.04.001
1062-9408/

American derivative pricing, many numerical methods have been presented attempting to price American options, including the lattice (Cox, Ross, & Rubinstein, 1979), finite difference (Brennan & Schwartz, 1977; Hull & White, 1990), and Monte Carlo simulation methods (Boyle, Broadie, & Glasserman, 1997). We note that Monte Carlo simulation methods are not initially designed for the valuation of American option prices. In the low-dimensional case, the finite difference method provides a more convenient way to price American options than the Monte Carlo method. Furthermore, increasing the number of steps comes at the cost of exponential growth in the size of the lattice pricing methods. Longstaff and Schwartz (2001) propose an algorithm for pricing American options called least-squares Monte Carlo (LSM) approach. This technique proceeds by simulating forward paths using the Monte Carlo simulation, and then performs backward iterations by applying least-squares approximation of the continuation function over a collection of basic functions. This algorithm is simple to implement within existing Monte Carlo frameworks, and has the additional advantages that the continuation functions are constructed explicitly and it is easy to calibrate to existing market prices. Based on the previously mentioned advantages, we then adopt this approach to approximate the American option prices.

Gold is a precious metal, which in recent years is considered to be an investment tool alternative to equity and bond markets. It provides similar functions as money in that it acts as a preserver of wealth, a medium of exchange and a unit of value. Unlike other commodities, gold is a special asset with renewable, relatively transportable, universally acceptable and easily authenticated. The unique and diverse drivers of gold price behavior not highly correlate with changes in other financial assets. As a consequence, this precious metal can contribute in a saving role by acting as a type of insurance against extreme movements and jumps in the value of traditional assets during times of economic and market stress (Baur & Lucey, 2010; Baur & McDermott, 2010; Beckmann & Czudaj, 2013; Capie, Mills, & Wood, 2005; Reboredo, 2013; Shahbaz, Tahir, Ali, & Rehman, 2014; Zagaglia & Marzo, 2013). Gold is a liquid asset, continuously quoted on spot and futures markets and easy to trade. In addition to Beckers (1984) and Ball, Torous, and Tschoegl (1985) empirically investigate the gold options market under the Black–Scholes framework, others, for instance, Ogden, Tucker, and Vines (1990) study gold spot and futures options. It is well known that the presence of jumps in the underlying asset price can have significant implications on pricing derivatives, but these aforementioned papers do not address such jump phenomena. The increasing number of jump events, especially after the subprime financial crisis of 2008, has created large fluctuations in the gold futures prices and related derivatives (e.g., American gold futures options). For the market development, it is crucial in capturing the dynamic jump process appropriately and price American gold futures options corresponding to the changing prices of gold futures.

The top panel of Fig. 1 draws some significant price jumps of gold futures in the daily data.[1] In particular, it shows that there are larger jumps (returns) in several time periods. In the oil crisis of 1979 and subprime financial crisis of 2008, for example, gold futures prices had larger jumps. The empirical data have revealed that the pure diffusion dynamics are not completely consistent with the reality, that is, the jumps do exist in the gold futures price realizations. Hence, incorporating sudden random shocks into a dynamic model is necessary and significant (Carr, Geman, Madan, & Yor, 2002; Eraker, 2004; Eraker, Johannes, & Polson, 2003; Maheu & McCurdy, 2004). In line with the changing gold futures returns in the bottom panel of Fig. 1, we could identify two regimes of the gold futures market. The first state is defined as the relatively low-volatility regime and can be viewed as the ordinary state. The second state is defined as the relatively high-volatility regime and can be regarded as the volatile state. In addition, we also find that, in the gold futures market, the bottom panel of Fig. 1 exhibits different arrival rates of jump events in different time periods. It is an empirical fact that there exists the so-called jump and volatility clustering in the logarithmic return series of gold futures prices caused by a period of time of high (low) arrival rates tend to be followed by a period of time of continued high (low) arrival rates. Nevertheless, the classical jump-diffusion processes, such as in Merton (1976), Amin (1993), and Kou (2002), are unable to address the phenomenon of volatility clustering. Duan, Ritchken, and Sun (2006) price options when there are jumps in the pricing

[1] The empirical data are from Datastream and cover the period from 1 January 1979 to 31 December 2010.