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Freight derivatives pricing for decoupled mean-reverting diffusion and jumps

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ABSTRACT

We develop an accurate valuation setup for freight options, featuring an exponential mean-reverting model for the freight rate with distinct reversion scales for its jump and diffusion components. We calibrate to Baltic option prices and analyze the freight rate dynamics. More specifically, we observe that jumps dissipate faster than the diffusive deviations about the equilibrium level. We benchmark against practitioners' model of choice, i.e., the lognormal model, and variants, and find that our approach reduces the pricing error while preserving analytical tractability and computational competence. We also find that neglecting fast mean-reverting jumps leads to nontrivial option mispricings.

1. Introduction

The evolution of modelling, operations management, and optimization techniques has transformed the shipping industry and various sectors have been restructured to take advantage of these innovations. Inevitably, these advancements affected also the bulk sector, an important sector of the world economy,[1] that demonstrated gradual revamping and utilization of newly developed tools aiming to appropriately capture the realism of a market characterized by uncertainty of future economic conditions and sluggish supply adjustment to changes in demand due to time-to-build lags, implying the need for sufficiently sophisticated approaches in shipping asset valuation.

In recent years, the trading volume of contingent claims in the market has grown rapidly. Kavussanos and Visvikis (2004) found that the introduction of freight derivatives trading decreased the price volatility, had an impact on its asymmetry, and improved the speed of information flow in freight markets. Options have gained acceptance as invaluable tools among market participants, not only for hedging physical exposures, but also for providing investors with versatility, including several expiration dates available for trading, as well as the ability to leverage and trade volatility. Freight derivative markets lack the liquidity of equity and conventional commodity markets, but this is now changing with the increasing participation of investment banks and hedge funds, in addition to traditional physical players such as shipowners, operators and trading houses. Alizadeh et al. (2015) have assessed the existence of liquidity risk and reported that this is priced and plays an

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[1] With over 80% of world merchandise trade being carried by sea, maritime transportation remains the backbone of international trade and a leading indicator of the global economy, which explains why the particular industry has attracted much interest in the finance literature (see Kilian, 2009; Kalouptsidi, 2014; Papapostolou et al., 2014; Greenwood and Hanson, 2015).

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important role in Forward Freight Agreement (FFA) returns. Moreover, freight forward/futures prices have been found to informationally lead the underlying freight rates (e.g., Kavussanos and Visvikis, 2004) and lag the commodity futures prices (Kavussanos et al., 2014). Alexandridis et al. (2017) have examined the spillover effects of time-charter rates, freight futures and options prices, and their association with trading activities and market liquidity of freight futures contracts; they have found significant information transmission in both returns and volatilities among the three markets.

In 2015, the equivalent trading volume in FFAs was approximately 640,000 cargo trading days, which was roughly equivalent to the full capacity of the underlying capesize fleet. The option market also appeared popular with a trading volume of 280,000 cargo days for 2015 and an average weekly open interest of 140,000 cargo trading days (source: www.balticexchange.com). Therefore, it is not surprising that the valuation and hedging of freight contingent claims have received attention from practitioners and researchers (see, for example, Koekebakker et al., 2007; Jørgensen and De Giovanni, 2010; Prokopczuk, 2011; Nomikos et al., 2013), especially from 2008 onwards; a period which was characterized by a notoriously high volatility.

Freight rates exhibit properties that distinguish them from other markets. Such are, for example, the high volatility, mean-reversion/cyclical behavior of rates and prices, and the non-storability of freight rates (e.g., see Kavussanos and Visvikis, 2006). Geman and Smith (2012) demonstrate that freight rate trajectories differ not only from traditional assets, such as stocks and bonds, but also from most commodities; electricity is a market that shares similar stylized empirical facts, such as absence of storability and high volatility. Maritime economic theory stipulates that, in a competitive freight market, rates are reverting[2] to long-run costs (Zannetos, 1966; Koekebakker et al., 2006). Poor market conditions and low freight rates halt investment in shipping projects, reducing eventually the supply of vessels due to increased demolition activity in a stagnant market (where excess tonnage is laid up). On the other hand, prosperous market conditions provide disincentives to scrapping and encourage new orders. Inevitably, new vessel deliveries shift gradually the supply curve to the right, putting downward pressure to freight rates. Consistently with this, several authors argue that mean-reversion is supported in freight rates. For example, Bjerksund and Ekern (1995) and Jørgensen and De Giovanni (2010) assume a Gaussian Ornstein–Uhlenbeck process for the spot freight rate, which, nevertheless, is not downward-restricted implying possible negative spot freight rates, especially when volatility is high, and is inconsistent with empirical facts about actual rates such as skewness. These deficiencies can be alleviated by using an exponential mean-reverting process as in Tvedt (1997, 2003). Adland and Cullinane (2006), instead, propose a non-parametric diffusion model for the freight rate dynamics in the tanker markets, which allows them to bypass potential parametric restrictions by estimating the drift and diffusion functions non-parametrically. More recently, focusing on Supramax spot rates, Benth and Koekebakker (2016) find evidence of volatility clustering and long-range memory effect, which they try to capture by means of a combined autoregressive with stochastic volatility model approach.

Another salient feature of freight rates is that of extreme price movements. Price discontinuities are observed during periods of tight supply and demand schedules due to the inability of supply to immediately respond to increased demand for seaborne transportation. Downside movements are also remarkable: for example, during the period 2003–2008, freight rates for capesize dry bulk carriers, with a cargo-carrying capacity of 180,000 mt dwt, increased from an average rate of 20,000 USD/day to a maximum of 236,000 USD/day only to drop to 6,000 USD/day within a period of four months after the onset of the financial crisis. Nevertheless, simply modelling freight rates using a classical diffusion model overlaid with jumps of normal size (Merton model, see Nomikos et al., 2013) results in jump shocks persisting for prolonged periods of time; the importance of additionally incorporating mean-reversion has been emphasized, for example, in Geman and Roncoroni (2006) when modelling power prices.

The purpose of this paper is to study the freight model with decoupled mean-reverting diffusive and jump components with distinct reversion scales, for the two largest in size dry bulk carriers, i.e., capesize and panamax, reflecting freight's distinctive self-adjustment behavior under tight and ordinary supply-demand patterns. We have seen previous use of such model construction in offshore shipping markets (Bjørkelund, 2014) with limited empirical application, though, due to inexistent derivatives' market for the offshore segment, but also in energy markets (e.g., see Hikspoors and Jaimungal, 2007 and Nomikos and Soldatos, 2008). Our contribution lies in deriving a relevant analytical formula for tradable average options and calibrating to market quotes of Baltic Capesize Index (BCI) and Baltic Panamax Index (BPI) options that are prevalent in the dry bulk market. By means of sensitivity analyses, we compare against simpler model constructions without jumps and/or two-regime mean-reversion, which market practitioners seem to have favoured so far due to their simplicity and analytical tractability. While maintaining these two desired features under the more sophisticated spot model proposed, we demonstrate its ability to reproduce stylized features of freight rates in the dry bulk sector. Our analysis of option pricing error statistics shows that the postulated model generates lower error than the basic lognormal. Moreover, a regression analysis shows that superimposing jumps on the spot rate diffusion improves on the option pricing biases.

The remainder of the paper is organized as follows. In Section 2, we present our spot and option price models. In Sections 3 and 4, we introduce our option data set and estimation procedure, whereas in Section 5, we perform our model validation and discuss the outcome from the empirical estimation of model parameters, analyze the option pricing errors, and compare with various nested models. Section 6 concludes.

[2] These models have been used extensively in the commodity literature to account for supply and demand fundamentals that induce reversion to some equilibrium level as commodity prices tend to fluctuate about values determined by the marginal cost of production; see, for example, the seminal papers by Bessembinder et al. (1995) and Schwartz (1997).