A CVaR approach to planning crude oil tanker fleet

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Crude oil, one of the most traded commodities, is primarily shipped between continents using (ultra) large crude oil tankers that have very high fixed and operating costs. Though at any given time the actual volume of global crude oil trade depends on the supply and demand dynamics and the related price volatility, an oil supplier is also exposed to the fluctuations in the tanker freight rates. This is because most oil suppliers own a certain number of tankers based on expected long-term demand, and make use of spot charter contracts and freight derivatives such as time charter contracts and options to meet service demand in excess of their owned-capacity. The existence of this *mixed-fleet* structure triggers costly bargaining in spot market, which can be compensated either by entering into longer term contracts or by becoming vertically integrated. From a financial point of view, this strategy exposes the oil supplier to different financial risks induced by uncertainties in both service demand as well as the charter markets. Thus, the oil supplier faces a fleet size and mix problem, which would entail managing a fleet of owned vessels plus a portfolio of assets (i.e., charter contracts and options). Through extensive literature review, we concluded that the financial implications of chartering contracts and options, and the corresponding mechanism to deal with the periodic adjustments of a crude oil tanker fleet have not been investigated.

In an effort to fill this gap, we first identify and quantify the associated financial risks. Note that though the oil supplier faces financial risks because of volatility in freight rates (i.e., *market risk*) and due to demand uncertainty (i.e., *enterprise risk*), we are more concerned about managing the downside of these risks due to its potential financial implications while aiming for a smooth operation rather than making short-term financial gains. Thus, we assume a policy of downside risk-aversion by enforcing enterprise risk control constraints (i.e., the risk associated with vessel under-utilization does not exceed an arbitrarily small threshold), while the market risks and chartering costs are minimized. To capture such downside risks, we make use of conditional value-at-risk (CVaR) measure. Finally, we propose an

analytical framework, i.e., a non-linear mathematical program and Monte Carlo simulation to estimate the stochastic parameters, which was tested on realistic size problem instances of an oil supplier. It is important to reiterate that the proposed non-linear integer programming model aims to minimize the total chartering cost and the financial risk, where the risk resulted from volatilities in both the oil demand and the freight rates.

The proposed framework made use of following five assumptions: *first*, all future demand and spot rates are stochastic and independent of each other; *second*, sufficient vessels are available in the spot market; *third*, all vessels are homogeneous in terms of capacity and charter rates; *fourth*, Asian options are available on time charter contracts; and, fifth, supplier updates its charter fleet segment at the start of each period.

Through numerous computational experiments it was concluded that the firm-specific financial risk (i.e., enterprise risk) is sensitive to the starting oil demand level. That is, it remains relevant if the starting oil demand is below the long-term mean, which increasingly becomes irrelevant at higher oil demand values. On the other hand, full use of a portfolio consisting of freight derivatives will be most useful in reducing the non-firm-specific risk (i.e., market risk), which is true in both the cases of spot freight rates starting lower or higher than the expected long-term mean. Finally, we note that these two types of risk move in opposite direction and hence their inverse relationship must be considered when making fleet size and mix decisions.

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