FreightMetrics

Measuring risk in shipping

by

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Shipping is a business where tough decision problems may arise in a number of different situations. Consider the following examples:

- The owner of a fleet of VLCCs is considering the following asset allocation choices:
  - Strengthen his position in the VLCC market by investing in another VLCC;
  - Expand in the tanker sector by investing in two Aframaxes;
  - Diversify his fleet by investing in the dry bulk sector.
- A chartering manager faces the dilemma of whether to fix his vessel for a single voyage at a high spot rate or seek a long-term time charter at a lower average rate.
- A charterer is worried about rising freight rates and needs to decide about whether to hedge or not, and just how much of the total exposure to hedge.
- A financier needs to determine the maximum advance ratio and pricing of a new loan.

The consequences of such decisions are far too serious, and potentially costly, to be left to chance, intuition or "expert" advice. Shipowners, charterers and banks alike need a systematic approach to back their decisions with better information and certain objective measures. What they really need is to understand the *risk* associated with a given situation and to use this information as a common yardstick for comparing alternate decisions.

Understanding risk

The first step towards understanding the risk involved in a strategic decision is measuring it. The task of measuring this risk is difficult because of the way risk links with the notion of *randomness*. After all how do you measure randomness?

The mathematicians have traditionally achieved measuring randomness using the notion of the (probability) *distribution*. A distribution assigns to each probable event a probability (a number that measures the likelihood of it happening). Knowing the distribution of a random process, one can ask questions like "how likely is it that interest rates will increase by more than 2 percentage points?" and get answers like "there is a 15% chance of this happening".

The future cash flow distribution

For a strategic decision in the shipping industry, a common question is "all things considered, how likely is it that future fleet cash flow will fall below zero?". Being able to answer this and other similar questions with statements of the form "there is a 30% chance of this happening", means that we are able to measure the risk involved in a strategic decision in a satisfactory way. Of course, to be able to do this, we need to know the future fleet cash flow distribution associated with the problem at hand.

Going back to the previous question, the phrase "all things considered" refers to the fact that the future fleet cash flow does not only depend on one factor that is subject to randomness. To mention a few, it depends on future freight rates, future interest rates and future oil prices. Recognizing the role of all these factors in the process of determining the future fleet cash flow, we usually refer to them as the "*risk factors*". These are the things that are really subject to randomness and in turn affect the cash flow of a fleet.

For a problem at hand, we normally fix an appropriate cash flow model that takes into account debt repayment and other cost items (e.g. operating expenses, drydocking costs, etc) and let the involved risk factors change in a correctly-distributed fashion. This means that we allow the factors to vary respecting their measure of randomness, namely their distribution. As the correct likelihood is assigned to each risk factor value, the correct likelihood of each cash flow outcome is revealed. This way the future fleet cash flow distribution is accurately determined.

Stochastic processes

But how do we get the risk factors to vary appropriately? What we need are processes that produce fictional risk factor data that respect the intrinsic characteristics of the real risk factor data. This is usually done using mathematical models that govern the price evolution of the risk factors. Of course these processes incorporate certain degree of randomness, so they are called *stochastic processes*.

As it is commonly recognized, in a shipping project, the primary risk factor affecting financial results, in terms of vessel valuations and fleet cash flow, is freight rates. It is therefore essential that we describe the future freight rate levels through a stochastic process. This will describe the way freight rates may evolve through time and will therefore produce a range of possible freight rate paths called *realizations*.

One such time path for the 1-year time charter rate of handysize bulkcarriers is shown in Figure 1. Even though it is not obvious by simply looking at the picture, only the period after August 1999 is actually generated by a stochastic process. For the period from January 1976 to July 1999 the freight rates on the path are the actual ones (source: Clarksons).

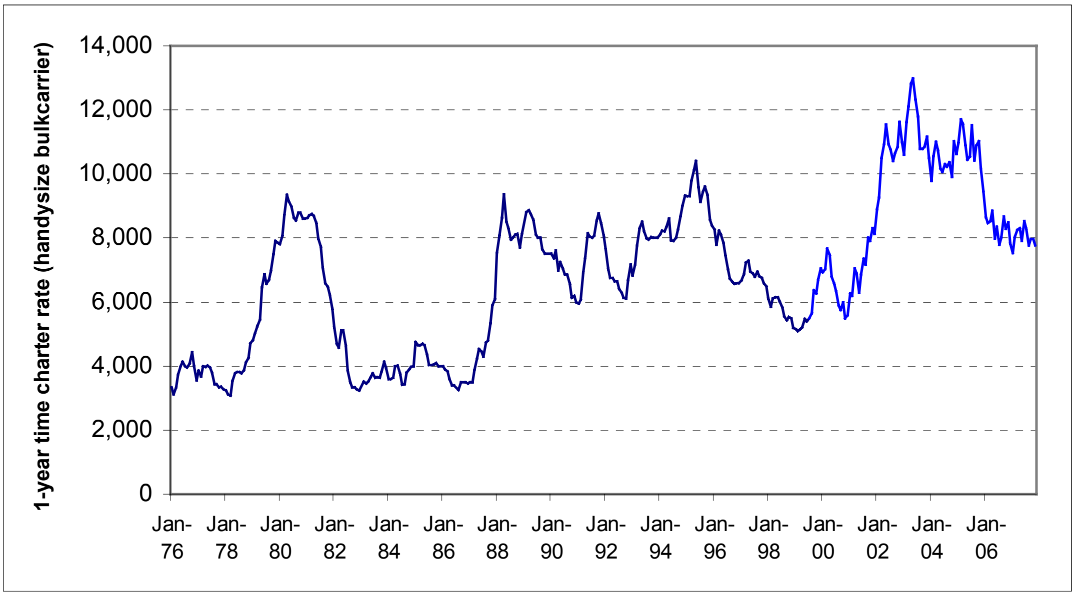

Figure 1: A path for the 1-year time charter rate of handysize bulkcarriers

Figure 2 shows several such paths generated by the same stochastic process. As a matter of fact, a stochastic process generates infinitely many possible paths. It is important to understand that the process does not specify the exact path that will be realized by the future freight rates. It only gives the general form of this path and all possible realizations.

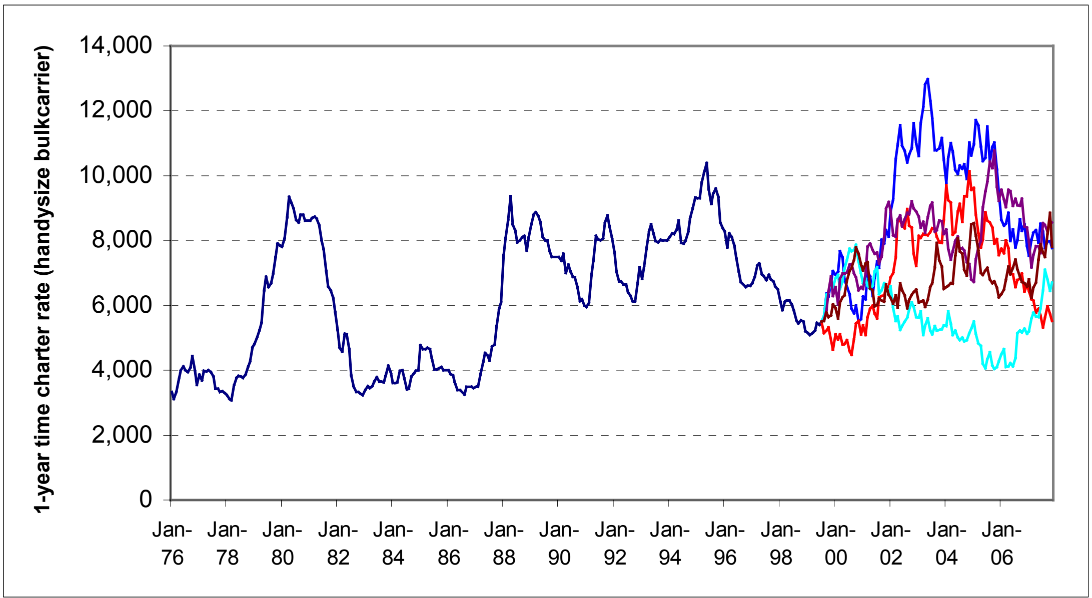

Figure 2: Several paths generated by the same stochastic process

Although each one of these paths seems completely random, the totality of the paths carries a huge amount of information. The way these paths are distributed and probabilities are assigned to them, gives a measure for the randomness of the future freight rates. For instance, notice that the terminal freight rate for the paths of Figure 2 is more often close to the $8,000 level than away from it and that the rates are moving lower as often as they move higher. Simply put, a stochastic process puts an order to randomness.

Monte Carlo simulation

Going back to the problem of determining the distribution of the future fleet cash flow, we want to use a stochastic process that accurately describes the future freight rates evolution, so that we produce a correctly-distributed set of possible freight rate paths that will be fed to our cash flow model. Then, through the cash flow model, the information carried by the totality of these paths will translate into information about the size of the risks involved in the shipping project that we examine.

The procedure that takes as input the stochastic process of a risk factor and produces a correctly-distributed large range of (simulated) paths for the factor's possible price evolutions is called *Monte Carlo simulation*. It is widely used in many mathematical applications and in particular for the pricing of derivatives and financial risk management.

When analyzing the risk in a shipping project, a Monte Carlo simulation is used to produce price paths for all risk factors involved. As a matter of fact, a simulation is run for all factors simultaneously. This means that each generated scenario consists of a time path for each of the risk factors. This scenario is then analyzed in the cash flow model as a whole. This allows for the scenarios to take into account the correlation among the prices of the various risk factors, for instance, between freight rates and interest rates. Thus, the scenarios carry any empirical information about the correlation of the risk factors to the cash flow model, so that the fleet cash flow is accurately determined.

Parameter estimation

There is a large number of stochastic processes that can serve as models for the price evolution of risk factors. Each one of them has certain characteristics that arise from its mathematical form and make it more appropriate for certain risk factors. It is the job of an analyst to determine the characteristics of a particular risk factor and thus choose a family of stochastic processes that share those characteristics.

The stochastic processes of the same family have the same general mathematical form and therefore the same characteristics. In the mathematical form are included certain numbers, called *parameters*, that vary among the processes of the same family. The values of the parameters of a particular process determine the magnitude of its characteristics.

After having chosen a family of stochastic processes that most appropriately describe the dynamics of a particular risk factor, the analyst has to determine the values of the parameters that best depict the behavior of the factor. This is usually done by looking at historic data of the risk factor and applying mathematical methods that will determine the parameter values that provide the best fit of the stochastic process to these data. Figure 3 shows the entire risk measuring process diagrammatically.

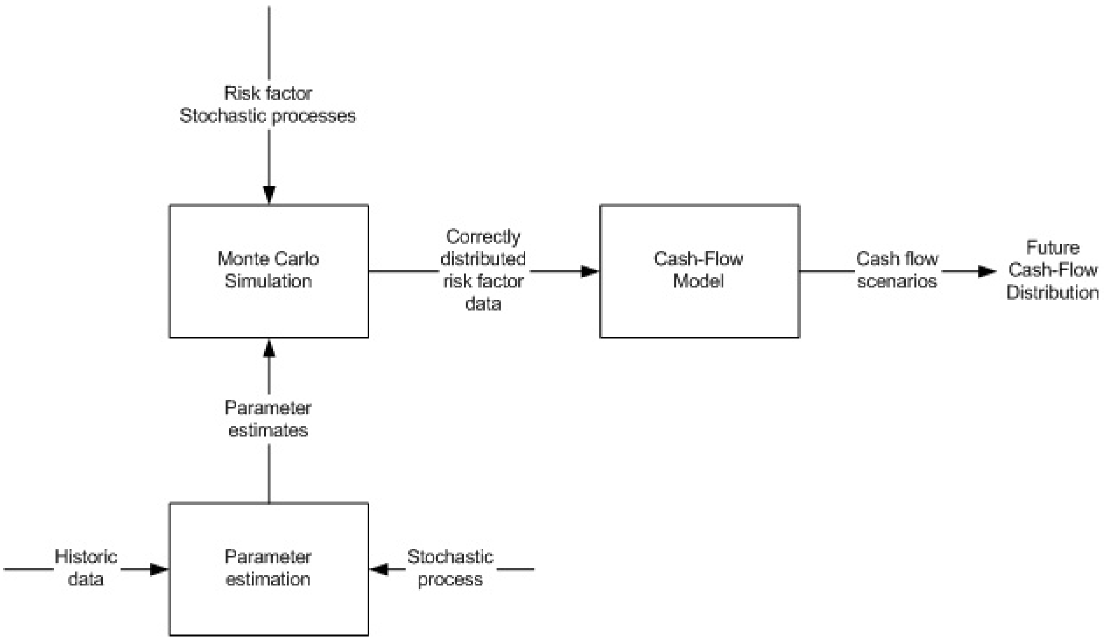

Figure 3: The risk measuring process

Freight rate characteristics

Before we examine some alternative stochastic processes that may be used to describe the dynamics of freight rate evolution through time, it is important to keep in mind the most commonly recognized characteristics of freight rates.

Cyclicality: The existence of cycles has long been accepted as part of the shipping business. The shipping cycle is often described as the process by which the market co-ordinates supply with changes in demand by means of market booms and slumps. Indeed, cycles can be seen as a mechanism devoted to removing imbalances in the supply and demand for ships. If there is too little supply, the market rewards investors with high freight rates until more ships are ordered. When there are too many ships it squeezes the cash flow until owners give up the struggle and ships are scrapped.

The presence of cycles does not mean that shipping markets are predictable, because cycles are too irregular to predict. Indeed it is impossible to predict when the market will move upwards (or fall), to estimate the extent of the swing or the duration of the phase. The length of the cycles is incidental, as shipowners are constantly trying to second guess the cycle, giving each cycle a distinctive character. For instance, if shipowners decide that an upturn is due and decide not to scrap their ships, the cycle just lasts longer. This is the reason why cycles are so irregular, in terms of their periodicity, their aptitude, and the position of the peak or of the trough of a cycle in progress. The cyclical behavior of freight rates can be captured by stochastic processes that allow for a pattern typically known as "*mean reversion*" .

Occasional market shocks: Freight rates sporadically exhibit positive or negative price "spikes" in the form of dramatic rate changes of 20% or more between successive months. The occurrence of such freight rate spikes appears to be more frequent and more pronounced in certain sectors, most notably the VLCC sector. This suggests the existence of suprise effects associated with random shocks generated by political or other exogenous events. The influence of such events in the shipping markets is well recognized and may provide a strong argument for the addition of a so-called "*jump*" component in the underlying stochastic process for freight rates.

Families of stochastic processes

The families of stochastic processes that are commonly used to describe the dynamics of financial instruments and commodities include:

The best known stochastic process is **Brownian motion**. It takes its name from the botanist Robert Brown who in 1827 studied the random movement of certain particles and it has been used extensively to describe random processes in many scientific fields. Its main characteristic is that price changes along each path (realization) are independent of each other. For this reason, it is often referred to as "*random walk*".

In Brownian motion future prices follow the *Normal* (bell shaped) distribution. Both the *mean* (the average future price) and the *standard deviation* (the size of the uncertainty of the future price) of this distribution depend on the time length until the future moment examined. The distance of the mean from the current price is proportional to the time length, whereas the standard deviation is proportional to the square root of the time length.

Brownian motion is a *continuous-time* process meaning that prices change at infinitesimal time intervals. Nevertheless, the easiest way to describe mathematically a Brownian motion is through a *finite-time* approximation. Then a simple mathematical equation relates the time passed to the corresponding change in price during that time:

$$\Delta S = \mu \cdot \Delta t + \sigma \cdot \varepsilon \cdot \sqrt{\Delta t}$$

where:

Δt	is the time change
ΔS	is the price change over Δt
μ	is the drift parameter
σ	is the volatility parameter
ε	is a random shock that follows the normal (bell shaped) distribution

The first term of the right-hand-side of the equation is *deterministic* (non-stochastic), whereas the second is *stochastic*. The "*drift*" determines the rate the mean grows where as the "*volatility*" governs the size of the variability of the process.

Figure 4 shows four different time paths generated by four Brownian motions with varying drift (μ) and volatility (σ) parameters, while keeping the same time change (Δt) and sequence of random shocks (ε).

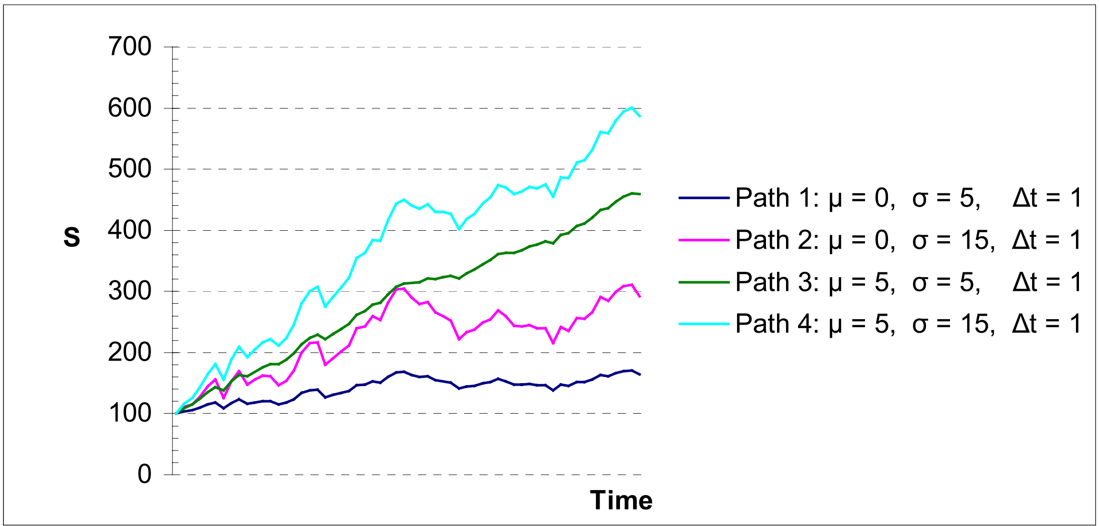

Figure 4: Typical Brownian motion paths with varying drift and volatility parameters

The **geometric Brownian motion** is a simple modification of the Brownian motion, where it is assumed that the returns of the prices rather than the prices themselves follow a Brownian motion. As a result, future prices cannot fall bellow zero (as it is often the case in reality) and follow a *Lognormal* rather than a Normal distribution. It is overwhelmingly used in finance to describe the dynamics of stock prices and commodities. Its mathematical form is similar to that of the Brownian motion. The drift and the volatility determine the expected growth and the variability of the prices.

$$\Delta S = \mu \cdot S \cdot \Delta t + \sigma \cdot S \cdot \varepsilon \cdot \sqrt{\Delta t}$$

where S is the current price and all other symbol are as above.

In a **mean reversion** process prices tend to return to a pre-specified level which serves as a long run equilibrium and it is called the "mean reversion level". Similarly to the Brownian motion, its mathematical form has two terms. The stochastic term is exactly the same to that of the Brownian motion and the size of the variability of the prices is governed by the volatility parameter.

The mean reversion is effected by the non-stochastic term whose size is proportional to the distance of the current price to the mean reversion level. If the current price is below the mean reversion level this term will be positive thus drifting the value higher towards the long run equilibrium where as if the current price is above the mean reversion level this term will be negative thus drifting the price lower again towards the long run equilibrium. The speed at which the prices drift toward the mean reversion level is governed by the "mean reversion rate" parameter. The general mathematical form of the process is the following:

$$\Delta S = \alpha \cdot (E - S) + \sigma \cdot \varepsilon \cdot \sqrt{\Delta t}$$

where:

Δt	is the time change
ΔS	is the price change over Δt
E	is the mean reversion level
α	is the mean reversion rate

σ is the volatility parameter and
ε is a random shock that follows the normal (bell shaped) distribution

In figure 5 two paths are shown. The first is generated by a Brownian motion and the second by a mean reversion. The two processes have the same volatility and the same sequence of random shocks has been used to generate the two paths. The mean reversion effect becomes more obvious when the price is further away from the long run equilibrium (here, $E = 100$).

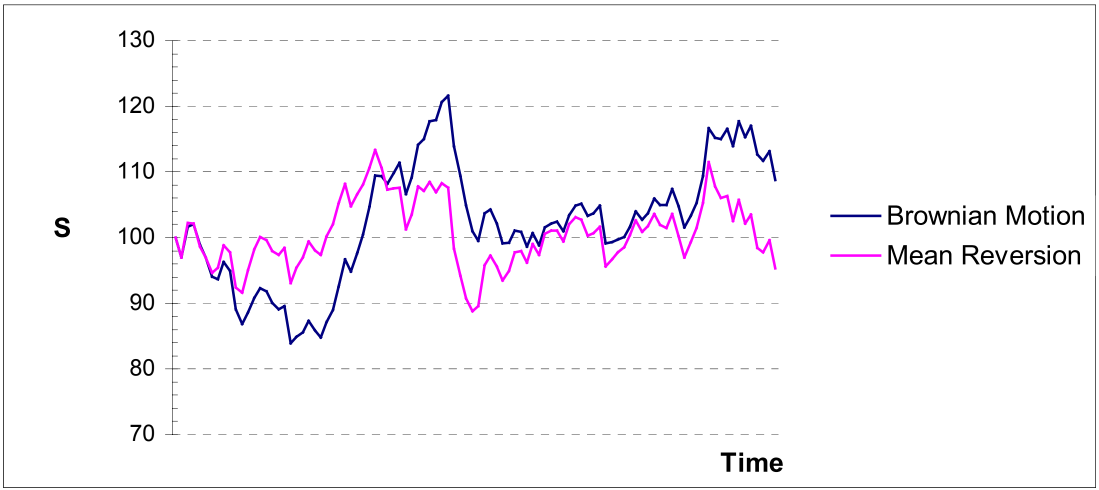

Figure 5: Two paths generated by the same sequence of random shocks

Mean reversion is very important in modeling freight rates because it captures their cyclical behavior.

Geometric mean reversion modifies the mean reversion process as the geometric Brownian motion modifies the Brownian motion. Returns rather than prices are governed by the mean reversion process. This restricts prices from falling below zero. The general mathematical form of the process is the following:

$$\Delta S = \alpha \cdot (E - \ln S) + \sigma \cdot S \cdot \varepsilon \cdot \sqrt{\Delta t}$$

Jump processes are designed to model instruments characterized by sudden and abrupt large price changes, often called "jumps". They are therefore important in freight rate modeling. They are commonly obtained from other processes by adding a "jump term" to the price change equation. This term is usually equal to zero but occasionally takes a large (positive or negative) value that produces the jump in the instrument's price. A so called "Poisson process" governs the frequency the jumps occur and it is independent of the other random sources of the process. The magnitude of the jump can be a pre-determined constant, although usually it follows an independent random process.

As an example of a jump process, the geometric mean reverting jump process has the following general mathematical form:

$$\Delta S = \alpha \cdot (E - \ln S) + \sigma \cdot S \cdot \varepsilon \cdot \sqrt{\Delta t} + \kappa \cdot J$$

where:

Δt is the time change
ΔS is the price change over Δt
E is the mean reversion level
α is the mean reversion rate

σ is the volatility parameter
ε is a random shock
J is the (random) size of the jump
κ is usually 0 and it equals 1 as often as the jump frequency requires

Figure 6 shows a path generated by a geometric mean reverting jump process. At this particular path two jumps have randomly occurred. They can easily be identified.

Figure 6: A path generated by a geometric mean reverting jump process

Conclusion

Using well-known mathematical tools and concepts (that in fact are already widely used in other industries for risk management purposes), we are able to model and calculate the risk of a shipping portfolio in a systematic and objective fashion. To accurately measure the impact of market variability on vessel valuations and fleet cash flow is a huge accomplishment and indeed the first step towards a complete risk management strategy. Having exposed the risk profile of a shipping project in quantifiable terms (i.e. by revealing the distribution of future cash flows), one is able to make objective risk-informed choices based on his view of the market and his risk preferences.

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FreightMetrics is a leading provider of software solutions and advisory services for risk measurement and management in shipping. For more information about FreightMetrics, visit www.freightmetrics.com.