Behind the Screens

The Mathematics of Market Value

Dr Alex Adamou describes the mathematical model behind VesselsValue automated online valuations.

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If the 2008 financial crisis has taught us anything, it is that economic modelling is not a game for beginners. Markets are composed of diverse participants interacting in complex ways. This gives rise to volatility and unpredictability. Nowhere is this more true than in shipping, where high volatility and "asset play" are the norm – indeed for many the raison d'être – and deals are often shrouded in secrecy and misinformation.

The unenviable task of valuing vessels in the midst of this chaos and darkness has traditionally fallen to shipbrokers, who use a combination of experience and recent sales to estimate the price a vessel might achieve between a hypothetical buyer and seller. There is much art to this process and no guarantee that two brokers will form identical opinions on the same vessel.

The development of an automated valuation system driven by market data therefore requires two main ingredients: a database of the highest quality and the widest coverage; and a mathematical model that incorporates the necessary broking intelligence to ensure valuations consistent with economic realities.

What Value?

First we must specify what we mean by "value". This is a highly contentious matter in the aftermath of 2008 and the subject of much debate in the academic and industry press. Here we mean the market value, defined as the sale price a vessel would be expected to achieve in a transaction between a willing buyer and willing seller under certain standard assumptions about the vessel's condition and legal status.

Other values are possible. Discounted cash flow value, widely used in accountancy, is the net present value of the vessel's future cash flows: revenues, operating costs, maintenance, and demolition. For highly specialised assets built for specific projects the most meaningful value may be the cost of building it anew. However, market value is the focus of this document.

Sale and Purchase

The primary source of data regarding vessel values is the sale and purchase (S&P) market. Although there is no official recording of sales, information filters through the network of buyers, sellers, and brokers before finding its way into broker reports, company press releases, and the industry's news media. This process is not dissimilar to "Chinese whispers" and accounts of sales do not always agree. We use our broking experience to collect and verify this information to produce a sales database of unrivalled coverage and accuracy.

When a sale includes an additional contractual term, such as a charter, this will have an associated value (possibly negative) which will confound the market value of the vessel itself. Such sales must be handled with care. Reliable information about ongoing negotiations can be used to ensure valuations keep pace with market developments, but again caution and in-depth market knowledge are required.

Five Factor Model

The academic literature and our own studies indicate that a vessel's value can be explained in large part by five factors: Type (e.g. VLCC, Capesize, QMAX, AHTS); Features (e.g. shipyard, hull, gear); Age; Size; and Earnings Sentiment.

Type

The shipping market is highly segmented: vessels carrying different quantities of different cargoes on different routes are governed by very different economics. These segments are manifested in the semi-official naming conventions (VLCC, Suezmax, Aframax, PSV etc.) applied to vessels on the basis of size, cargo, and their ability to negotiate certain canals or ports. Although long-term trends may be common to all segments when they are linked to global economic factors – such as the inflation and collapse of last decade's asset price bubble – spot issues relating to particular cargoes or routes can make short-term trends uncorrelated. Therefore, our model treats each ship type independently.

Features

The global commercial fleet exhibits great heterogeneity, particularly among smaller vessels running more specialised trades. A vessel's features and specification have a significant effect on its value. For example, an Aframax with coated tanks capable of accepting refined products will, ceteris paribus, command a premium over an Aframax that can carry crude oil only. Similarly, buyers will pay more for a vessel built at the most reputable yards than for an identical vessel whose keel was laid by a less established builder.

The differences in value resulting from these multifarious features are an irreproducible part of the shipbroker's art, as there are many more permutations than can be analysed in a purely data-driven way from the information available. Therefore, our brokers have used their knowledge and experience to assign scores to all the features recorded in our vessel database, which our research analysts have converted into a rules-based module which interfaces with our algorithms.

Age

The effect of age on a vessel's value is not a simple matter of depreciation by a fixed amount or percentage. A vessel has a finite but unknown lifetime over which to generate earnings after which its value is that of its scrap steel. Put in these terms, the difference in value between a brand new vessel and a sister built the year before is small, because the extra earnings are uncertain and far in the future. This implies gentle depreciation in the first few years. However, the difference between the same vessels as they approach the end of their careers will be rather larger and the depreciation more rapid, before their values level off at scrap. Other factors, such as design improvements and supply-demand differences for vessels of particular ages, also come into play.

Size

Most commercial vessels earn money by carrying cargo, so their value depends on the amount of cargo they can carry. We refer to this as size. Typically it is measured in deadweight tonnes (DWT) for tankers and bulk carriers, twenty-foot equivalent units (TEU) for containerships, and cubic metres (CBM) for gas carriers. Vessels which earn money in different ways – such as offshore tug and supply units – have different notions of size indicating their capacity to do remunerative work. For example, an anchor handling tug has its size measured in brake horsepower (BHP).

Even within a type, a vessel's value does not increase in direct proportion to its size. Chartering practices mean that there is often an optimal size for each type, such as 180,000 DWT for Capesize bulkers. Vessels smaller or larger than this will be less valuable per unit size because, for example, they cannot accept a full load at some ports or they have the burden of spare capacity to transport.

We model the inherently nonlinear dependences of value on age and size using flexible mathematical functions. These have adjustable parameters which allow them to assume a wide variety of shapes, within sensible limits imposed by economic principles and broking expertise.

Earnings Sentiment

That vessel values are correlated with earnings rates (usually measured in USD per day) is a well-established principle within the industry and makes sound economic sense. However, finding the best proxy for market sentiment from the plethora of published earnings rates is far from straightforward. Indeed, some sectors do not have well-publicised rates and other indicators may be used. Even when appropriate data have been chosen, considerable signal processing is still required for accurate modelling. Spot rates contain much irrelevant noise and must be smoothed. Values react to movements in the chartering markets, so a lag must be applied.

Furthermore, it is essential to characterise how the sale and purchase market reacts not only when earnings are close to their historical averages, but also when they are unusually high or low. We have studied the variation of vessel values with earnings rates over the last decade, including the rollercoaster of 2007-09, to determine a relationship valid even at the extremes. Judicious selection and processing of data allow us to achieve very high correlations between value and earnings signals for most vessel types. A robust model of how values depend on earnings is particularly important during periods in which few vessels are bought and sold. By using earnings data, which are typically reported daily, our model can bridge the gaps between sales and produce accurate valuations even when S&P activity is slow.

Algorithms

Having established how to model these five factors, the next step is to use actual sales to calibrate the model. Specifically, the parameters which determine the shapes of the mathematical functions for age, size, and earnings are adjusted to match the sales data as closely as possible. Finding these best fit relationships requires mathematical and computational techniques known collectively as regression analysis.

Straight line regressions can be performed with minimal expertise in popular spreadsheet packages. However, these are not suitable for our purposes since our relationships are nonlinear (curved).

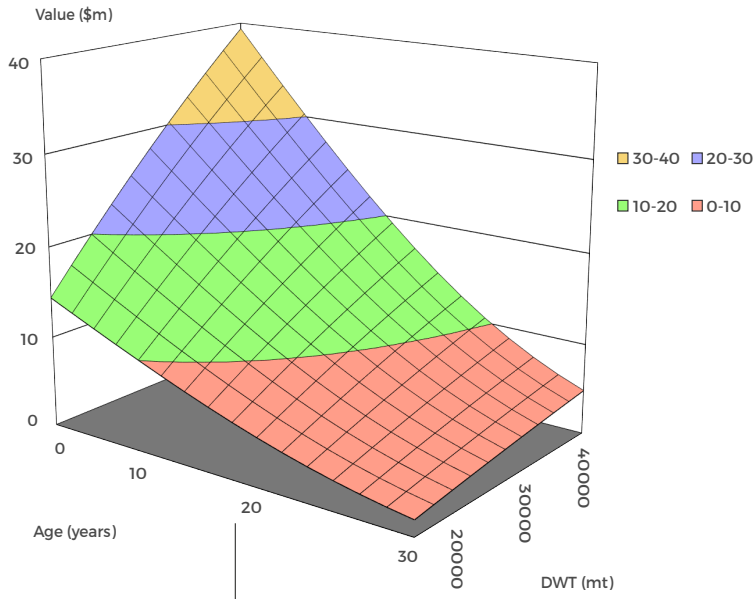

Figure 1. Surface plot of value against age and deadweight for a Handy bulker with standard features and earnings of $10,000 per day.

In fact, our relationships are not lines at all, straight or curved. Rather they combine to form multi-dimensional surfaces, with one dimension for each of value, age, size, and earnings. Figure 1 shows an example surface obtained by fixing one of the variables (earnings) at a constant level, in this case for a Handy bulker.

The difficulty is that the relationships which form these surfaces can't be determined independently of each other. It is impossible to use sales data to find only the age relationship if we are unable to adjust the prices for size, but we can't obtain the size relationship we require without first being able to adjust for age. We are trapped by circularity.

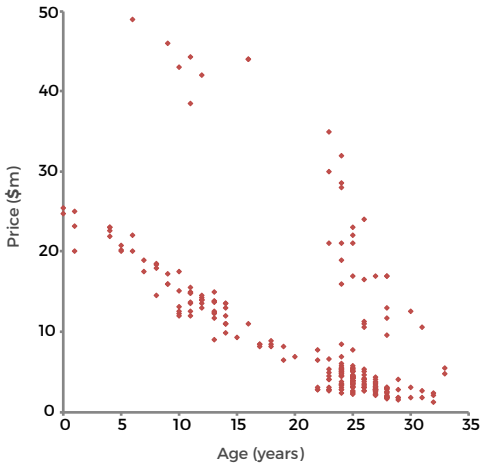

Figure 2. Historical sales of Handy bulkers over a two year period plotted against vessel age.

To illustrate this problem, Figure 2 shows historical sale prices of Handy bulkers over a two year period plotted against vessel age. Some sales took place before the 2008 crash at high prices while the remainder occurred afterwards at more modest levels. Confounded by the wide range of market conditions present on this graph, not to mention a variety of sizes and features, it would be very difficult to plot a single meaningful curve through this data.

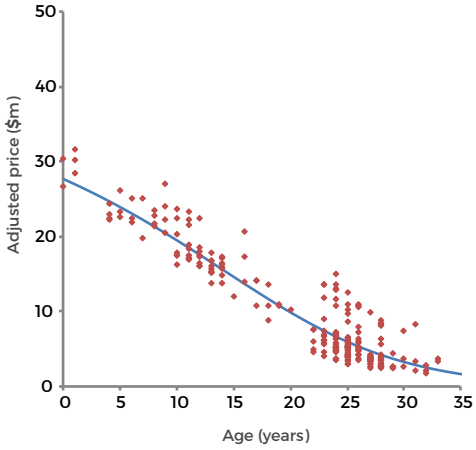

Figure 3. Sales from Figure 2 adjusted for features, deadweight, and earnings (red). Best fit curve (blue).

The solution is to find the relationships simultaneously. However, doing this for a model of such complexity requires advanced regression techniques and sophisticated optimisation algorithms beyond the capability of standard spreadsheet packages. We have built a team of quantitative analysts and software developers to build, test, and refine a bespoke computer program to perform this analysis. Figure 3 shows the sales from Figure 2 after adjustment for features, size, and earnings. A strong relationship between sale price and age is now evident and a best fit curve can be drawn.

Our software is run daily so that our model is continually recalibrated to reflect the latest sales and earnings information. In some sense this can be viewed as an application of artificial intelligence. As new data come in, our system learns and reacts to produce the most accurate and up-to-date valuations. This helps our customers stay abreast of market developments. However, technology which ignores human knowledge and experience is dangerous, which is why we take care to ensure that our methods are always firmly rooted in broker expertise.

Accuracy

Our customers are sophisticated market participants who insist on understanding the methodology behind our valuations. But what they are really interested in is accuracy because that is what affects their bottom line. This is where our system is truly unique. By using only the data that would have been available on the day before each was sold, we can perform valuations of all vessels whose sales have been reported and compare these with the actual prices achieved. Transactions in circumstances unreflective of market levels are excluded. Unlike a human, our software has no hindsight, making this a true test of how it would have performed. Crucially, this allows us to measure and report our accuracy. Currently we are unaware of other valuators offering this.

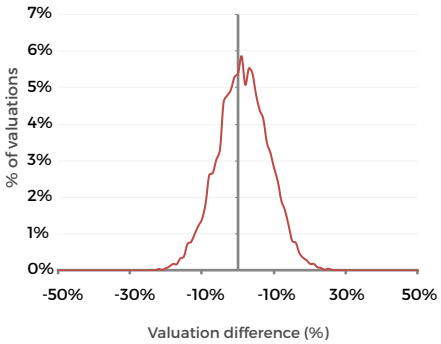

Figure 4. Distribution of the percentage difference between model value and sale price for 3,705 sales between 2011 and 2016.

Figure 4 shows the results of this "back-testing" as a frequency distribution of the percentage difference between the model value and the realised sale price. A positive difference indicates that the valuation was greater than the sale price. The distribution is centred on zero and narrow, indicating that the model has no systematic bias and strong predictive power. The data are also summarised in Table 1.

Valuation difference	% of sales
+/- 1%	13.3%
+/- 2%	22.0%
+/- 3%	30.6%
+/- 4%	38.7%
+/- 5%	46.1%
+/- 10%	75.6%
+/- 20%	97.5%
+/- 30%	100.0%

Table 1. Summary of the accuracy data in Figure 4.

It is worth remarking that "difference" is not the same as "error". Although it would be hubris to claim that our valuations were entirely error free, there are many reasons why a valuation might differ from the actual sale price. For example, the vessel may have been in especially good or bad condition. Furthermore, not all transactions are equally advantageous for buyer and seller and occasionally there are bargains to be had on both sides. Therefore, a certain amount of variability will always be present.

We believe that the inherent advantages of an automated valuation system, in particular the ability to process enormous quantities of data in a rigorous and scientific way, combined with exceptional data quality and broking intelligence make our valuations the best in the business.

The Future of Shipping

The computerisation of stock exchanges in the 1980s brought many economic advantages and heralded a new age for the finance industry which has lasted to this day. We believe that automating the vessel valuation process brings the same advantages to our customers in the shipping industry.

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