Value based trading of real assets in shipping under stochastic freight rates

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Abstract: The paper uses a real options valuation model with stochastic freight rates to investigate market efficiency and the economics of switching between the dry bulk and the tanker markets in international shipping. A dry bulk carrier is replaced with a tanker when the expected net present value of such a switch is optimal from a real options based decision rule. Depending on the development of the markets a reversal may take place later. The cost and demand parameters upon which the decisions to switch are made, including the stochastic characteristics of freight rates, are estimated from an empirical analysis that is updated every week throughout a 12-year time period from 1993 to 2005. The second-hand market for bulk ships seems to have been efficient most of these years in the sense that market switching usually did not pay off, with one major exception: it seemed profitable in expectation to leave the dry bulk market and enter the tanker market over a significant period of time shortly after the millennium shift, and to return to dry bulk market about three years later. These points in time corresponded with an unprecedented boom period in the tanker and drybulk freight markets, respectively, and the result suggest that agents in the second-hand market were slow to adjust their expectations. In retrospect, such an investment policy also happened to be profitable compared to staying put in the tanker market, even after accounting for transaction costs.

Keywords: Investment, uncertainty, trading rules, valuation, market switching.

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1. Introduction

Timing of investment is a key to success in international shipping. This is because freight rates are sometimes very high for long enough periods of time to make a ship look more like a money machine than a normal production unit. In other periods they are close to or even below average long-run costs including normal returns to capital. In this article we apply a real options based model to study the optimal timing of investment in the sense of switching between the two main freight market segments in bulk shipping, namely that for tankers (the sea transport of crude oil and oil products) and dry bulk carriers (the sea transport of dry commodities such as iron ore, coal, and grain). The model is calibrated to real world data on freight rates and second-hand ship values, and it seems to do a fairly good job in estimating when a switch from one market segment to the other could be profitable. The model and the empirical results are also used to discuss market efficiency.

The theoretical real options model used here is in the tradition of McDonald and Siegel (1986). The modelling of combined entry-exit decisions was introduced by Mossin (1968) and generalized in a modern real options framework in Brennan and Schwartz (1985) and Dixit (1989). Leahy (1993) showed how to interpret such models in a perfectly competitive market, which is our framework of analysis.

According to Koopmans (1939), the short-term supply curve in bulk shipping can be characterized by two distinct regimes, depending on whether or not the fleet is fully employed. When the fleet sails at close to the maximum capacity, the aggregate supply function becomes almost perfectly inelastic resulting in very high freight rates. Conversely, when the available supply exceeds demand, leading to lower freight rates and vessel unemployment, the least cost-efficient vessels withdraw from the market, resulting in a series of perfectly elastic steps in the short-term supply function. Boom periods have historically been followed by periods of depressed freight rates, due to a strong supply side response through newbuilding activity. This cyclical nature of the freight rates in turn leads to cyclical and very volatile ship prices. Obviously a ship has greater value if freight rates and operating income are high, but if changes in ship values are predictable then there is money to be made from market timing. In shipping this is referred to as *asset play*. An asset play investor has typically a fairly short investment horizon compared to the typical lifetime of a ship of 25 years or more. Another timing strategy is to switch between freight market segments based on the freight rate differential and relative ship values. If asset play or market segment switching provides easy profits, then the (second-hand) market for ships is not informationally efficient. In this article we focus on the latter investment strategy, but before describing our own model we give a brief review of the maritime economic literature concerning ship valuation, investment strategies and market efficiency.

What is the value of a ship? The maritime literature has borrowed heavily from financial economics over the past decades. Beenstock (1985) and Strandenes (1984) introduce the present value model of ships in maritime economics. The price of a ship today is the discounted value of the ship the next period plus the freight revenue during the period. This present value relationship says that the market is efficient if market participants discount future cash flows properly. If market participants are rational (or semi-rational as suggested by Strandenes (1984)), then markets are efficient. Such a framework suggests that ship prices are largely unpredictable. This conclusion spurred a series of empirical investigations of market efficiency by Vergottis (1988), Hale and Vanags (1992), Glen (1997), Tsolakis et al. (2003), Kavussanos and Alizadeh (2002) and Adland and Koekebakker (2004).

Kavussanos and Alizadeh (2002) test the efficient market hypothesis within the rational expectation framework in the market for new and secondhand dry bulk ships. They follow the VAR methodology of Campbell and Schiller (1988), which enables a direct test of the joint hypothesis of rational expectation and market efficiency. The conclusion from the empirical part of their study is that the efficient market hypothesis must be rejected for the dry bulk sector. Birkeland and Tvedt (1997) discuss asset play in tanker trades under the assumption of mean-reverting freight earnings. In their model a company owns at all time minimum one and a maximum of five ships. The model is only in part based on economic valuation in the sense that an asset transaction occurs when an *ad hoc* markup of expected revenues over costs is observed. Adland and Koekebakker (2004) investigate asset play strategies in the second market for bulk ships. They use an entry-exit model where the buy and sell signals are generated by technical trading rules. They find that profits from trading rules exceed a simple buy and hold strategy in both the dry bulk and tanker sectors. However, these trading rules are governed by short term trends in the asset values, leading to frequent trading. Moreover, when the strategies are adjusted for transaction costs and illiquidity in the secondhand market, the excess profits evaporates, leading to the conclusion that the sale and purchase markets (S&P) for ships are fairly efficient.

Asset pricing can be viewed in absolute or relative terms. The present value model of ship value is an absolute valuation relationship, relating freight revenues to the price level of an asset. Absolute asset pricing is a difficult exercise with wide error margins, which also explains the mixed results reported above. But what about the relative price of ships in different market segments? The law of one price says that two assets that produce the same future payoff should sell at the same price and is an example of perfect relative pricing. If it does not hold, arbitrage opportunities exist. Chen and Knez (1995) argue that in the more general case where markets are integrated, assets with similar payoffs across future states should have similar prices. In a measure-theoretic framework they develop relative price bounds that allow for examination of near integrated markets.

The concept of relative valuation has been used for generating trading strategies in the general financial literature. For instance, Gatev et al. (2005) conduct an empirical study of relative pricing in the stock market using a trading strategy called pairs trading, explained as follows: Pick two common stocks that have moved together in the past. If they deviate in value, buy the cheap one and sell the expensive one. If history repeats itself, prices will converge once more and the speculator will profit. Turning to bulk shipping, there are two main sectors, the drybulk and tanker markets. Since ships are typically designed to operate in one of these markets only, high freight rates in one market segment does not automatically produce high freight rates in the other segment. However, Beenstock and Vergottis (1993) argue that freight rates in these two markets cannot drift too far apart due to shipbuilding and scrapping activity, as well as the existence of a special ship type (the *combination carrier*) that can operate in both segments. Their arguments are as follows: Increased contracting of tankers reduces the potential future supply of new drybulk carriers as shipbuilding capacity is scarce. This will ultimately lower tanker freight rates relative to drybulk freight rates. Furthermore, in times of strong transportation demand for oil relative to dry bulk commodities, the fleet of combination carriers will switch to the tanker market from the drybulk market and increase supply in the short run until increased newbuilding activity and subsequent deliveries restore the market balance. Such a switch reduces the tanker rates relative to dry cargo rates. Following this line of reasoning, the two freight markets are more integrated the older the fleet of dry or tanker vessels (making scrapping a viable option) and the larger the fleet of combination carriers. When two markets are integrated, then so should ship prices be according to Chen and Knez (1995).

In this article we propose to use a real options based entry-exit model for switching between these two market segments in shipping. We assume that a ship operator will always own and operate one ship, but he can switch back and forth between the two segments. If he initially operates in oil transportation, then, in order to make a switch, he must sell his oil tanker and buy a dry bulk carrier. The discussion above suggests that these market segments are integrated, indicating that the freight rate in one segment cannot drift too far away from the freight rate in the other segment. The key variable in the model is therefore the freight rate differential, which is modelled by an Ornstein-Uhlenbeck (mean-reverting) process.

Imagine a perfectly competitive market with two truly comparable valued ships – one dry bulk carrier and one tanker – and where switching could occur at no cost. In such a market switching would take place immediately if the observed freight rate differential deviated from the theoretical value that reflects the long-term cost differential. When transaction costs are introduced, an upper and lower barrier to switching will exist due to the combination of uncertainty and irreversibility. These barriers for investment are identified by the entry-exit model of this paper. If ships in the two segments are priced efficiently, the freight rate differential can be expected to lie between the two barriers (inside the "hysteresis band"). If the freight rate differential moves outside this band of inaction, there is an indication of inefficient relative pricing as switching is expectedly profitable.

The rest of the paper is organised as follows: Section 2 provides some basic insights in the decision problem of the paper by a general discussion of market switching and market efficiency. Section 3 contains the theoretical model. In section 4 the estimation and calibration routine is explained. Empirical results are presented and discussed in section 5, while section 6 concludes.

2. Market switching and market efficiency

Suppose that a ship owner with restricted access to capital and other resources is bound to operate exactly one ship in either of two markets. One market is considered the default market that yields a default cash flow. A fixed entry cost is required to initiate operations in the other market. Operations in the latter market may then be suspended by incurring a fixed exit cost. Then a second entry may take place, and so it goes. When is it optimal to switch from one market to the other? The answer is well known from the real options theory on entry and exit under uncertainty. As long as the freight rate processes satisfy certain characteristics, it is optimal to enter when the net freight rate differential (in terms of earnings) exceeds a fixed, upper trigger level. A similar rule applies in the reverse case; i.e, a return to the base case market occurs when a certain lower differential is reached. Irreversible transaction costs and uncertainty explain the inertia. When the freight rate is between the two trigger levels it is optimal to remain in the current state of operation. The cost parameters and the characteristics of the price process will determine the exact location of the triggers.

What if the firm is not alone with this option to invest or disinvest, but one firm among a large number of (potential) entrants? Then one should expect massive entry as soon as entry is optimal for a single firm. Such an increase of supply will prevent the freight rate from rising far above the trigger rate for investment. In the theoretical ideal situation with a large number of identical entrants, the freight rate will not increase a dollar above the trigger level, but the trigger level will act like a reflecting upper barrier for the freight rate. Similarly, the exit trigger will act like a lower reflecting barrier. This theoretically ideal evolution of prices is illustrated in Fig. 1, which plots a simulated random walk with and without two specific barriers.

< Figure 1 inserted here >

The grey line in Fig. 1 shows how freight rates would have been in the case of a single monopolistic firm, i.e., without aggregate supply adjustments. The black line shows the constrained process with two specific barriers. The lower barrier is touched first. This leads to a positive differential between the constrained and the unconstrained process. The differential stays constant as long as the constrained random variable wanders between the two barriers, but it will drift off in some direction in the very long run as one of the processes is unconstrained. The unconstrained process in Fig. 1 can be interpreted as a more fundamental demand process than the solid line price process, as the unconstrained process does not depend on the supply side in an industry context.

When the firm is to determine the trigger price at which to invest or divest, it does not matter which one of the two processes is used. This striking result is due to Leahy (1993). In other words, the firm's decisions can be based on myopic preferences. Profits are affected as the true price process is bounded in both ends, but the optimal decision rules are not.

No real market where prices are unregulated will produce price ceilings and price floors as exact as those shown in Fig. 1. One reason is that firms are never identical in terms of costs. There will also be slight differences in terms of quality, branding etc., making any real market different from a market with perfect competition. Other distortions also come into effect. The prices will often stay relatively close to some mean value in the very long run, but with no absolute price ceiling or floor. With a sufficiently large variation of competing technologies a mean-reverting price process could therefore result. The long-term mean price should be closely related to long-term costs as long as the markets are efficient, with free entry and free exit.

At least three candidates for a stochastic process exist that may be used when searching for the optimal decision rules in markets as discussed above: (1) the underlying demand process, (2) a price process without mean-reversion but with barriers, or (3) a mean-reverting price process without barriers. The last candidate is the most promising one for our purposes, considering not only the available information on the world's bulk markets, but also the technical challenges that arise with the two other alternatives.

The analysis in the subsequent sections applies a mean-reverting price process without price ceilings and price floors, and with parameters that are estimated from historical data.

Referring to the theoretical discussion above, one should keep in mind that a random walk between an upper and a lower price barrier that fluctuate over time, might well be a more realistic representation of the exact price process.

3. Theoretical model

In this section we describe an optimal asset play strategy in terms of a policy for switching between the two market segments, *dry bulk* and *tankers*, based on the general discussion above. More details are found in the Appendix and in Sødal et al. (2005). (In the latter reference, the model is used to value the flexibility embedded in combination carriers that can operate in both market segments. This requires another empirical setup and a quite different interpretation of variables.)

The decision maker is a shipping firm with some kind of capacity constraint that prevents it from operating many different assets at the same time. However, the firm is able to switch between the two ship types depending on what ship is expectedly more profitable from available information on freight rates, ship prices and costs. More precisely, we make the following assumptions:

1. An investor must at all time own exactly one ship that can operate in exactly one of the two market segments. He is allowed to switch back and forth between the two market segments an infinite number of times by selling and buying ships of comparable size.
2. The buying and selling of ships is done in the secondhand market. The price of a secondhand ship in each of the two segments is denoted I_{wet} and I_{dry}.
3. All ships are assumed to have infinite lifetime.
4. The discount rate is constant (ρ).
5. The transaction cost of a switch – i.e., brokerage fees etc. – is also constant (F).

The appropriateness of these assumptions is discussed in the empirical section below. The most important variable in the theoretical model is the differential (the spread) between freight rates in the dry bulk and tanker freight market segment. The dynamics of the freight rate spread is described by an Ornstein-Uhlenbeck (O-U) process

$$(1) \quad dp = \mu(m - p)dt + \sigma dz$$

where p ($=p_{wet}-p_{dry}$) is the freight rate differential between the two market segments, m is the long run mean for this spread, μ is a mean-reverting speed parameter, σ is a volatility parameter and dz is the increment of a Wiener process.

What is the value of a switch compared to staying put in the initial market segment? A switch incurs investment costs plus either a short or a long position in the freight rate differential. Look first at the investment costs. The total investment cost when switching from the dry bulk segment to the tanker segment is

$$(2) \quad A = F + I$$

where $I = I_{wet} - I_{dry}$. The similar total cost for a switch the other way, denoted B, equals

$$(3) \quad B = F - I$$

since the component I of the total investment now has been reversed. When the price of the secondhand oil tanker exceeds that of the dry bulk carrier by more than the brokerage fee, B will be negative. Still we have $A+B>0$, which is required for irreversibility (i.e., one cannot get rich by switching back and forth all the time).

Next, look at the freight rate differential. Denote the expected, discounted value of future freight differentials at time t by V_t, assuming no further switches. This revenue would be obtained by switching to the other sector and remaining there forever. For the given O-U process it becomes

$$(4) \quad V_t = E\left[\int_t^{\infty} p_s e^{-\rho s} ds\right] = \left[\int_t^{\infty} \left(m + (p_s - m)e^{-\mu s}\right)e^{-\rho s} ds\right] = \frac{p_t}{\rho + \mu} + \frac{\mu m}{\rho(\rho + \mu)}$$

where $E[\cdot]$ is the expectations operator and p_t is the current freight rate differential; see Dixit and Pindyck (1994, p. 74). Eq. (4) shows that V_t is a linear function of the current differential, p_t. By Ito's lemma, V_t follows the Ornstein-Uhlenbeck process

$$(5) \quad dV = \mu(\tilde{m} - V)dt + \tilde{\sigma} dz$$

where $\tilde{m} = m / \rho$ and $\tilde{\sigma} = \sigma / (\rho + \mu)$, and where the time subscript has been omitted.

Suppose that the shipping firm is initially in the tanker segment but has decided to switch to the dry bulk segment when the freight rate hits a certain p_H, and to return when another freight rate p_L ($<p_H$) is hit next. The Appendix shows that the value of the switching opportunities equals

$$(6) \quad W_0 = \frac{Q(p_0, p_H)\left(V_H - A - Q(p_H, p_L)(B + V_L)\right)}{1 - Q(p_L, p_H)Q(p_H, p_L)}$$

where p_0 ($<p_H$) is the current freight rate differential and V_H and V_L are expected net present values of future earnings evaluated at the trigger points p_H and p_L, assuming no further switches. $Q(x,y)$ is a discount factor function that applies to the motion from a current freight rate x to another freight rate y. Thus $Q(x,y)=1$ for $x=y$ and $0 \leq Q(x,y)<1$ for $x \neq y$. The discount factor function is specific to the stochastic process. It could also matter whether the motion is upward or downward, so generally $Q(x,y)\neq Q(y,x)$. For the O-U process the discount factor becomes

$$\text{(7a)} \qquad Q(p_L, p_H) = \frac{M(p_L) - R^{-}U(p_L)}{M(p_H) - R^{-}U(p_H)}, \qquad R^{-} = \lim_{p\to-\infty} \frac{M(p)}{U(p)}$$

$$\text{(7b)} \qquad Q(p_H, p_L) = \frac{M(p_H) - R^{+}U(p_H)}{M(p_L) - R^{+}U(p_L)}, \qquad R^{+} = \lim_{p\to+\infty} \frac{M(p)}{U(p)}$$

where $p_H > p_L$ and

$$\text{(8a)} \qquad M(p_L) = KummerM\left(\frac{\rho}{2\mu}, \frac{1}{2}, \frac{\mu}{\sigma^2}(m - p_L)^2\right)$$

$$\text{(8b)} \qquad U(p_L) = (p_L - m) KummerM\left(\frac{1}{2}\left(1 + \frac{\rho}{\mu}\right), \frac{3}{2}, \frac{\mu}{\sigma^2}(m - p_L)^2\right)$$

KummerM(·) is the confluent hypergeometric function, which has the following series representation (Slater, 1960):

$$\text{(9)} \qquad KummerM(\theta, b, z) = 1 + \frac{\theta}{b}z + \frac{\theta(\theta+1)z^2}{b(b+1)2!} + \frac{\theta(\theta+1)(\theta+2)z^3}{b(b+1)(b+2)3!} + \ldots$$

In order to determine whether it is optimal to switch market, the value function (6) with underlying definitions is maximized with respect to p_L and p_H. If the firm is currently operating in the tanker market, a switch to dry bulk is induced if the current freight rate differential exceeds p_H. Likewise, a switch in the other direction is induced by a freight rate differential below p_L. Based on the main result in Leahy (1993), it can be argued that the two market segments are efficient in a relative sense (i.e., relative to each other) if the observed freight rate differential stays within the hysteresis band $[p_L, p_H]$. In the next section we present the data along with a discussion of the modelling assumptions above.

4. Modelling assumptions and parameter estimation

Under the stated assumptions, optimal investment boils down to the question on when to sell a drybulk carrier and replace it with an oil tanker and vice versa. The decision will depend on the current secondhand price differential for ships, I_0, the discount rate, ρ, the current freight rate differential, p, and the stochastic properties of the freight rate differential as given by (1) under appropriate estimates for m, μ, and σ.

Newbuilding and secondhand ship values

The ship types we consider are Suezmax oil tankers and Capesize dry bulk carriers, which are of comparable size (around 150,000 dwt). The switching model could be of interest to several ship types and market segments, but to reduce the significance of errors in variables not modelled explicitly it is natural to choose ships that are comparable in size and costs. If one ship were much more expensive or is characterized by economies of scale or scope (such as a combination carrier) one would have to put more effort into modelling other operations within the firm, other investment options and the opportunity costs of capital. Such issues can be more or less ignored when restricting to markets that are fairly similar and easy to characterize as they mainly differ in freight rates and secondhand prices in the short run.

Fig. 2 plots the newbuilding prices for Suezmax and Capesize bulk carriers between 1986 and 2005. The clear upward shift in oil tanker newbuilding prices early in the 1990s is probably related to the double-hull requirement that was introduced around that time.[1]

<Figure 2 inserted here>

In our model we focus on secondhand values, or more specifically on the price difference between an oil tanker and a dry bulk carrier that are both five years old. Fig. 3 shows the price development for such ships.

<Figure 3 inserted here>

The dotted line in Fig. 3 represents the variable *I* in the theoretical model and shows that the price differential is positive during most of the data period. This means that tankers are usually more expensive than dry bulk carriers. In practice this results from greater steel consumption due to the double hull requirement and the fact that tankers are more complex in terms of construction and onboard equipment. The assumption that all ships are five years of age is trivial as long as secondhand markets are balanced in the sense that secondhand ships of different age are priced correctly relative to each other. That is reasonable as all such ships are available immediately. The economics of investment in new ships is more complicated due to delivery lags which also fluctuate. In general, delivery lags can have spurious effects on investment; see Bar-Ilan and Strange (1996) and Sødal (2006).

Since all ships are assumed to have infinite life-times, the discount rate must be raised accordingly to account for depreciation. Discounting is dominated by the volatility of freight rates in the short run, so infinite life-times is probably not a crucial assumption in the model. The empirical analysis will show that success with the market switching strategy does not depend highly on interest rates but mostly on how decisions are made conditional on the evolution of freight rates and secondhand prices.

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[1] Note the graphical illusion after 2003, which indicates a smaller price differential than the actual one due to rising absolute prices. Still the differential is somewhat lower than in the previous years.

It should also be emphasized that the model considers all costs to be fixed. Selling one ship and buying another one is regarded as a net investment based on the current price differential. This means that the investment strategy does not consider explicitly the uncertainty of secondhand prices. Since the uncertainty of freight rates, which is indeed modelled, tends to be positively correlated with price uncertainty for ships, this simplifying assumption could have systematic erroneous impact on investment valuation. Since uncertainty of freight rates is modelled explicitly, however, the magnitude of the error is intuitively small albeit in principle unknown.[2]

Freight rate differential

Fig. 2 and Fig. 3 indicate that secondhand prices are more volatile than newbuilding prices. The recent experience in the secondhand market is exceptional, with the price for five years old ships at some occasions even exceeding the newbuilding price. Record-high freight rates is the main explanatory factor, as the opportunity cost of waiting many years for the delivery is correspondingly high. This is seen from Fig. 4, which plots monthly spot freight rates in the dry bulk and the tanker market after 1990.

<Figure 4 inserted here>

Fig. 4 demonstrates increasing uncertainty and increasing freight rate spread over time as the overhang of tonnage created in the 1970s and 1980s slowly disappeared and gave way to a tight balance of supply and demand. The thin line in Fig. 4 is the freight rate spread which is the driving process in the model. The volatility increases dramatically in the end of the sample period, so the empirical estimates will vary depending on the choice of data period. Some changes could be predicted by the market, partly due to increased newbuilding costs for oil tankers following from political decisions and technological change, and partly due to a shrinking combination carrier fleet, all of which could be observed. This suggests that the parameters of the O-U process are not constant over time. One might have picked a more sophisticated stochastic process for the freight rate differential, but then the analytical tractability of the model would be lost. Another possibility, the one we pursue, is to re-estimate the parameters when new observations enter the sample window.

Parameter estimation

The discrete time counterpart to the O-U process in (1) is the AR(1) process given as

$$(10) \qquad p_t = \alpha + \beta p_{t-1} + \varepsilon_t$$

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[2] See Dixit and Pindyck (1994, ch. 6) for a model with combined price and cost uncertainty.

where α and β are constants and $\varepsilon \sim N\left(0, S^2\right)$. Here $X \sim N(a,b)$ means that a random variable X is normally distributed with mean a and variance *b*. In this model, unbiased estimates of α and β can be found from an ordinary least squares regression. The relationships between the parameters in the discrete time model in (10) and the continuous time version in (1) are given by

$$\text{(11a)} \qquad \mu = \frac{-\ln \beta}{\Delta}$$

$$\text{(11b)} \qquad m = \frac{\alpha}{1 - e^{-\mu\Delta}}$$

$$\text{(11c)} \qquad \sigma = \sqrt{S^2 \frac{2\mu}{1 - e^{-2\mu\Delta}}}$$

where S is the standard deviation of the residuals of the regression and Δ is the time between observations measured in years. We will use weekly data on the freight rate differential, resulting in $\Delta=1/52$. In the next section the model is calibrated to real world data. As discussed above, the model must be re-estimated frequently to adjust for changing market conditions. We will use a sample window of three years for the model estimation. For a slowly mean-reverting process, although unbiased, one would need a long time series to get precise estimates of the parameter α in (10) and consequently the long run mean, *m,* in (1). Therefore the long run mean is instead derived from an equilibrium argument. Differences in newbuilding prices between tankers and dry bulk carriers are likely to translate into equivalent freight rate differences in the long run for a competitive market. As long as the discount rate and the newbuilding cost differential are stable over time, and since the O-U process is symmetric around its mean, it can be argued that *m* will correspond to the annualized capital cost difference between tankers and bulk ships. This is used in the empirical analysis, which assumes

$$\text{(12)} \quad m = \rho I_0$$

where ρ is a constant discount rate and I_0 equals 75 percent of the newbuilding price differential between new ships and five years old ships.[3] Newbuilding prices fluctuate but the price differential between tankers and bulk ships of comparable size can be expected to fluctuate less due to integrated shipbuilding markets. This follows from the fact that many shipyards can produce both types of ships and that, at the aggregate level, the capacity (per time unit) to produce ships is constrained.

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[3] 25 percent value reduction is close to the average long-term price differential between new ships and five year old ships in this market, bulk carriers as well as tankers.

5. Empirical analysis

When uncertainty is limited to freight rates and the process for the freight rate differential is autonomous as it is here (i.e. not depending on calendar time), the optimal policy follows from the discussion in section 2. The firm should switch market segment, selling the tanker and buying a dry bulk carrier, when the freight rate differential exceeds the secondhand price differential by a certain upper margin. The decision to return is based on a similar rule.

Parameter estimation and model calibration

In practical market switching situations historical data will be combined with other knowledge to form plausible predictions for freight rates and other variables. In our context, backward-looking empirical behaviour would tend to underestimate the importance of change. We use a sample window of three years for parameter estimation. Three years is a normal delivery lag for new ships and can be seen as a typical long-term response time on the supply side when the market is exposed to demand changes. Data and estimation details are given below:[4]

1. We have collected weekly spot freight rate in the dry and tanker sector and computed the freight rate differential for the period January 12, 2001, to May 20, 2005, a total of 802 observations. On December 18, 1992, we use the previous three years of data (154 observations) and run an OLS regression for the AR(1) model described in (10). The estimates for σ and μ are computed from (11a) and (11c).
2. Monthly prices for Suezmax tankers and Capesize bulk carriers for the period January 1990 to May 2005 are used to compute differences in newbuilding prices. For December 1992 we use the previous three years of data (36 observations) as an estimate for I_0. The base case discount rate is set to ρ=0.1 (10 percent year) embodying 5-6 percent interest and 4-5 percent depreciation. The parameter m is computed from (12).
3. Monthly observations of secondhand prices for Suezmax tankers and Capesize bulk carriers over the period January 1990 to May 2005 are used to compute differences in secondhand prices. In December 1992 we use the prevailing price difference as an estimate of I.
4. The market switching strategy consists of determining the optimal triggers p_L and p_H from (6) using the parameter values found in step 1-3, and to switch market whenever

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[4] All our data was kindly provided by Clarkson Research (2005).

it is optimal from the given decision policy. (The optimal triggers are found by maximizing the value function, W_0, numerically over a grid.)

5. The sample window is then moved one week ahead, and steps 1-4 are repeated until the end of the sample (May 20, 2005). The estimated trigger points, p_L and p_H, are recorded at each recalibration.

Note that since we only have monthly prices on ship values, and the model is calibrated weekly, the parameter values of I and m can only change every fourth week.

Results

Fig. 5 shows the development of the freight rate differential and the optimal barriers for investment between December 1992 and May 2005. All three types of data are computed weekly, but the figure plots the average values over the last four weeks, reflecting that even an asset play strategy requires a reasonable response time and the fact that some empirical data are based on monthly observations. The main conclusion is that the market seems to have been efficient in a relative sense during most of the sample. The freight rate is located in between the barriers up until July 2000. The strategy under such conditions is to sustain operations. The freight rate approaches and is apparently reflected by one of the investment thresholds at several occasions. The theory discussed in section 2 makes it reasonable to believe that the true stochastic process could be a random walk within two barriers as opposed to a process with an always active mean-reversion force. Alternatively, it could be a combination of these alternatives. For practical purposes the difference may not be crucial: what matters are the estimates for the investment triggers.

< Figure 5 inserted here >

We note that the double-hull requirement increased the long-term investment costs for tankers relative to dry bulk carriers. A well-functioning market will anticipate such a change by expecting relatively higher future freight rates in oil trades than present and historical rates. Accordingly, both thresholds in Fig. 5 would be lowered in the first part of the data period by accounting for this external effect.

The resulting decision policy implies that a switch to the tanker market would be profitable for several months in the second half of the year 2000. The size and duration of the shock in terms of freight rates outside the hysteresis band of in-action can be interpreted as a clear advice. A slightly less clear advice to switch appears early in 2003, before an advice to invest in dry bulk later in fall the same year. The trigger points in mid-2000 and late 2003 corresponds very well with the start of the recent boom markets in the tanker and drybulk freight markets, respectively, with freight rates in the latter case rapidly reaching levels never before seen in the recent history of the global shipping markets. This suggests that either the agents in the secondhand markets were slow to change their expectations or that the rolling window estimation procedure of our empirical implementation is incapable of incorporating this structural change in freight rate levels and volatility sufficiently quickly. The markets have been extremely volatile from then on. This is reflected in the decision policy with a time lag since the policy is based on a three-year sliding average. Still the hysteresis band widens up fast, so the recommendation is to stay constantly in dry bulk trades. (There is a very short exceptional period early in 2005, in a market situation wilder than hardly ever before in peacetime. Most investors would probably hesitate to follow the advice of a model like this one literally under such circumstances.)

The real history is but one possible among an infinite number of paths for the evolution of the market prices. Therefore the economic implications of following the recommendation of the decision policy do not say much about the quality of the policy. More extensive testing is needed for that. Puzzling enough, however, a ship owner who initially operated in the dry bulk market, switching to the tanker market in July 2000 as recommended by the market switching strategy, and returning in October 2003, would have made excess profit compared to non-switching strategy. He would have paid 10 million dollars more for the tanker he bought in July 2000 than for the one he sold in October 2003, in addition to one million dollars in transaction costs. However, the net present value of the freight income would have been more than 14 million dollars higher, implying a net gain of 3.7 million dollars when ignoring some minor interest payments. A firm that missed the opportunity in 2000 but switched to the tanker trades in January 2003 and returned in October 2003 would also have made a small gain. Freight earnings but also the price for the tanker purchased in January 2003 would have been lower, and the net gain around one million dollars.

Except for interpretation, the theoretical model used here is like one derived by Sødal et al. (2005). The latter reference studies the profitability of combination carriers, a ship type capable of operating in both of the bulk market segments in question. It does not investigate relative market efficiency, but only the value of flexibility based on a pure valuation approach. A combination carrier increases in value as the hysteresis band between the tanker and dry bulk sector increases. The main variable of interest, the freight rate differential, need not be outside the bands in order for such an investment to be profitable. Few such dual-purpose ships have been built during the last decade due to high price tags, and none are on order. Sødal et al. (2005) conclude that the profitability of combination carriers has increased, so this situation may well change in the near future. If it does, the dry bulk and tanker freight markets will become more integrated once again. The empirical set-up behind the investment rules of this paper adjusts automatically to such changing circumstances as they evolve.

Sensitivity analysis

As shown in Fig. 6, the conclusions above appear not to be very sensitive to changes in the discount rate, which has been varied from 7 percent to 15 percent. This result is comforting as the discount rate was treated simplistically in order to make the model tractable.

< Figure 6 inserted here >

Fig. 7 shows that the model is also quite insensitive to changes in transaction costs. The brokerage fee is usually not a fixed amount but a certain percentage of the price (the seller usually pays around 1% commission), but it is treated as a fixed parameter in the model for technical reasons. Varying this parameter between \$300,000 and \$700,000 does sometimes make a difference with respect to the location of the barriers, but one that apparently does not very often matter for the decision on whether to switch market or not.

< Figure 7 inserted here >

We conclude that the base case discount rate and switching cost – i.e, 10 percent and \$500,000, respectively – are representative for the model even if the exact choice of these numbers can always be questioned in such a simplified model.

5. Concluding remarks

In this article we have provided a model for switching between integrated markets. It is based on economic valuation using real options techniques modelling. If two markets are integrated, an investor should switch market if the real assets in the other market drops sufficiently in value in a relative sense. The opposite applies for the investor to switch back. This provides a framework for analysing the relative efficiency of two integrated markets. If money can be made from timing the markets, the two markets are inefficient in a relative sense.

In the empirical analysis we applied the model to two main market segments in international shipping: the tanker market and the dry bulk market. The model was calibrated to real world data using a three-year estimation window. It turned out that the freight rate differential remained inside the estimated hysteresis band most of the time. This indicates that no excess profits can usually be made from the switching strategy – the markets are informationally efficient in a relative sense. At the end of our sample, however, the model indicates market timing abilities. In fact, all the switches suggested by the model would have paid off. Still it is much too early to pass the judgement that these market segments are informationally inefficient. First, the model identifies only a few excess profit opportunities and it is not evident how to judge the statistical significance of these results. Second, testing for market efficiency, in an absolute or relative sense, often encounters the “joint-hypothesis” problem. Our model is based on the assumption that the freight rate differential process adequately picks up the uncertainty in the investment situation and that it can be described by an Ornstein-Uhlenbeck process. Misspecification of the underlying uncertainty may mistakenly be taken as evidence of relative inefficiency.

For the stochastic and highly volatile shipping markets one should not pay much attention to the results from a single example. Future work should include more extensive testing of the market switching strategy with more market segments, a variety of time periods, and adjustments for changes in technologies and economic policies of significance to the shipping markets. Revisions that could make the strategy more realistic should also be considered. This includes explicitly modelling the secondhand markets for ships, more rigorous lifetime considerations, and improved modelling of frequent market segment switching.

One possible application of the model would be to link it with the pairs trading strategy considered in Gatev et al. (2005). They use an ad hoc trading rule (sum of squared deviations between two normalised price series) to determine the thresholds. Here we have presented an economic valuation model for determining such thresholds.

References

Adland, R. O. and Koekebakker, S. (2004): “Market efficiency in the second-hand market for bulk ships”, Maritime Economics and Logistics, (6), pp. 1-15.

Beenstock, M. (1985): “A theory of ship prices”, Maritime Policy and Management, 12(3), 215-225.

Beenstock, M. and Vergottis A. (1993): “The interdependence between the dry cargo and tanker markets” Logistics and Transportation Review (29), pp. 3-38.

Birkeland, S. and Tvedt, J. (1997): “Freight rates and tanker values – empirical findings and implications for asset play”, Working Paper 25, SNF/Norwegian School of Economics.

Brennan, M. J. and Schwartz, E. S. (1985): “Evaluating natural resource investments”, Journal of Business 58, pp. 135-157.

Campbell, J. Y. and Schiller, R. F. (1988): “Stock prices, earnings and expected dividends”, Journal of Finance, 43, 661-676.

Chen, Z., and Knez, P. J. (1995): “Measurement of market integration and arbitrage”, Review of Financial Studies, 8(2), 287-325.

Chang, H-B, Choi, J. Y. and Chang, Y-T (1996): “Price behavior in the Baltic freight futures market”, IAME, Annual Conference Proceedings 1996 (International Association of Maritime Economists).

Clarkson Research (2005): Shipping Intelligence Network, www.clarksons.net

Dixit, A. K. (1989): “Entry and exit decisions under uncertainty”, Journal of Political Economy 97 (3), pp. 620-638.

Dixit, A. K. and Pindyck, R. S. (1994): Investment Under Uncertainty, Princeton University Press.

Dixit, A.; Pindyck, R. S. and Sødal, S. (1999): “A markup interpretation of optimal investment rules”, Economic Journal 109 (455), pp. 179-189.

Gatev, E. G., Goetzman, W. N. and Rouwenhorst, K. G. (2005): “Pairs trading: Performance of a relative value arbitrage rule”, Review of Financial Studies (forthcoming).

Glen, D. (1997): “The market for second-hand ships: further results on efficiency using cointegration analysis”, Maritime Policy and Management, (24), pp. 245-260.

Hale, C. and Vanags, A. (1992): “The market for second-hand ships: some results on efficiency using cointegration”, Maritime Policy and Management, (19), pp.131-140.

Kavussanos, M. G. and A. Alizadeh (2002): “Efficient pricing of ships in the dry bulk sector of the shipping industry”, Maritime Policy and Management, 29(3), 303-330.

Kavussanos, M. G. and A. Alizadeh (2003): “The price-volume relationship in the sale and purchase market for dry bulk vessels”, Maritime Policy and Management, 30(4), 321-337.

Koopmans, T. (1939): “Tanker freight rates and tankship building”, De Erven F. Bohn, Haarlem, Netherlands.

Leahy, J. (1993): “Investment in competitive equilibrium: the optimality of myopic behaviour”, Quarterly Journal of Economics 108(4), pp. 1105-1133.

Mossin, J. (1968): “An optimal policy for lay-up decisions”, Swedish Journal of Economics 70, pp. 170-177.

McDonald, R. and Siegel, R. (1986): “The value of waiting to invest”, Quarterly Journal of Economics 101, pp. 707-728.

Strandenes, S. P. (1984): “Price determination in the time-charter and second-hand markets”, Working Paper no. 6, Centre for Applied Research, Norwegian School of Economics and Business Administration.

Sødal, S. (2006): “Entry and exit decisions based on a discount factor approach”, Journal of Economic Dynamics and Control (forthcoming).

Sødal, S., Koekebakker, S. and Adland, R. (2005): “Market switching in shipping – a real option model applied to the valuation of combination carriers”, Submitted Working Paper, Agder University College.

Tsolakis, S. D., Cridland, C. and Haralambides, H. E. (2003): “Econometric modelling of second-hand ship prices”, Maritime Economics and Logistics, 5, 347-377.

Vergottis, A. (1988): “An econometric model of world shipping”, PhD-thesis, City University Business School, London.

Appendix

This appendix derives the value function W_0 of eq. (6). Following the methodology of Sødal (2006), consider the optimal timing problem of when to enter or exit a market for which the expected net present value of remaining in the market forever equals a stochastic variable V as described in the text. The evolution of the net present value is given by the Ito process

$$\text{(A1)} \qquad dV = \mu_V dt + \sigma_V dz$$

where the Ornstein-Uhlenbeck case in eq. (5), for which $\mu_V = \mu(\tilde{m} - V)$ and $\sigma_V = \sigma$, is just one example. The entry cost is a constant, A, and the exit cost a similar constant, B. We require $A+B>0$ to establish some irreversibility in the model, but either A or B could be negative. The initial value of the stochastic variable equals a fixed V_0, the firm is not operating at the initial point, and V_0 is assumed to be so low that immediate entry is not optimal. (The decision policy does not depend on the initial freight rate spread, V_0, so this fixed initial value is just a technical necessity in this context.)

As argued by Dixit (1989) and others, the optimal decision is to enter as soon as a certain V_H is reached and to exit as soon as a certain V_L ($<V_H$) is reached after the first entry. Then entry will take place the next time V_H is hit, and so on. The firm finds the optimal policy by a two-step procedure. First, the current expected net present value of a decision policy that uses two *arbitrary* values V_L and V_H is found. Then the *optimal* policy is found by maximizing this expected net present value with respect to V_H and V_L.

The (net present) value of the firm at the initial point, $W_0=W(V_0)$, can be written

$$\text{(A2)} \qquad W_0 = Q(V_0, V_H)(V_H - A + F(V_H))$$

where $Q(V_1,V_2) \equiv E[e^{-\rho T}]$ is a decreasing function in V_2 for a fixed V_1, equivalent to the expected discount factor when moving from V_1 to V_2. Furthermore, T is the first-hitting-time from V_1 to V_2; see Dixit et al. (1999). The formula (A2) can be explained as follows: Starting outside the market at V_0, all future revenues and costs are discounted by $Q(V_0,V_\mathrm{H})$ to account for the time until the first investment. Then the entry cost A is incurred, after which the value of the firm is V_H plus the value of further investment options, $F(V_H,V_L)$. The latter is generally a function of both V_H and V_L; see Dixit and Pindyck (1994).

Exit will take place as soon as the stochastic variable hits V_L. This implies that the value of the remaining investment options at time of entry can be written as

$$\text{(A3)} \qquad F(V_H, V_L) = Q(V_H, V_L)(-V_L - B + W_L)$$

This formula reflects that the net present value of further operations at time of exit, V_L, is lost at time of exit when the exit cost B is incurred. The firm still has value W_L as it keeps the option to enter and exit later on. As long as $V_0<V_L$, it must also hold that

(A4) $$W_0 = Q(V_0, V_L)W_L$$

because the value of the firm when $V=V_L$ is the discounted value of its initial value. Moreover, the discount factor when moving from V_0 to V_H can be decomposed into two legs – from V_0 to V_L and from V_L to V_H – as follows:

(A5) $$Q(V_0, V_H) = Q(V_0, V_L)Q(V_L, V_H)$$

see Dixit et al. (1999). By definition we also have $Q(V_i,V_j)=Q(p_i,p_j)$ for $i,j = 0$, L or H. Then eq. (6) in the text is easily obtained by combining (A2) through (A5).

Note the following nice interpretation of eq. (6): the numerator contains the net present value of the two first options (entry and exit); the denominator accounts for the ability to repeat this procedure infinitely many times as the expected discount factor for each cycle is $Q(p_L,p_H)Q(p_H,p_L)$, comprising the movement in both directions between p_L and p_H.

As shown by Dixit et al. (1999), the discount factor $Q(V_1,V_2)$ for a particular Ito process (A1) is found by solving the differential equation

(A6) $$\tfrac{1}{2}\sigma_V^2 Q''(V_1, V_2) + \mu_V Q'(V_1, V_2) - \rho Q(V_1, V_2) = 0$$

Here primes denote first and second derivatives of Q with respect to the first argument. Two boundary conditions apply. Firstly, $Q(V_1,V_2)=1$ for $V_1=V_2$ as no discounting applies when investment takes place immediately. Secondly, $Q(V_1,V_2)\rightarrow 0$ when V_1 and V_2 get far enough apart (implying that the target value V_2 is hit in a very distant future). The solution for the Ornstein-Uhlenbeck process given by eq. (8ab) is derived in Sødal et al. (2005).

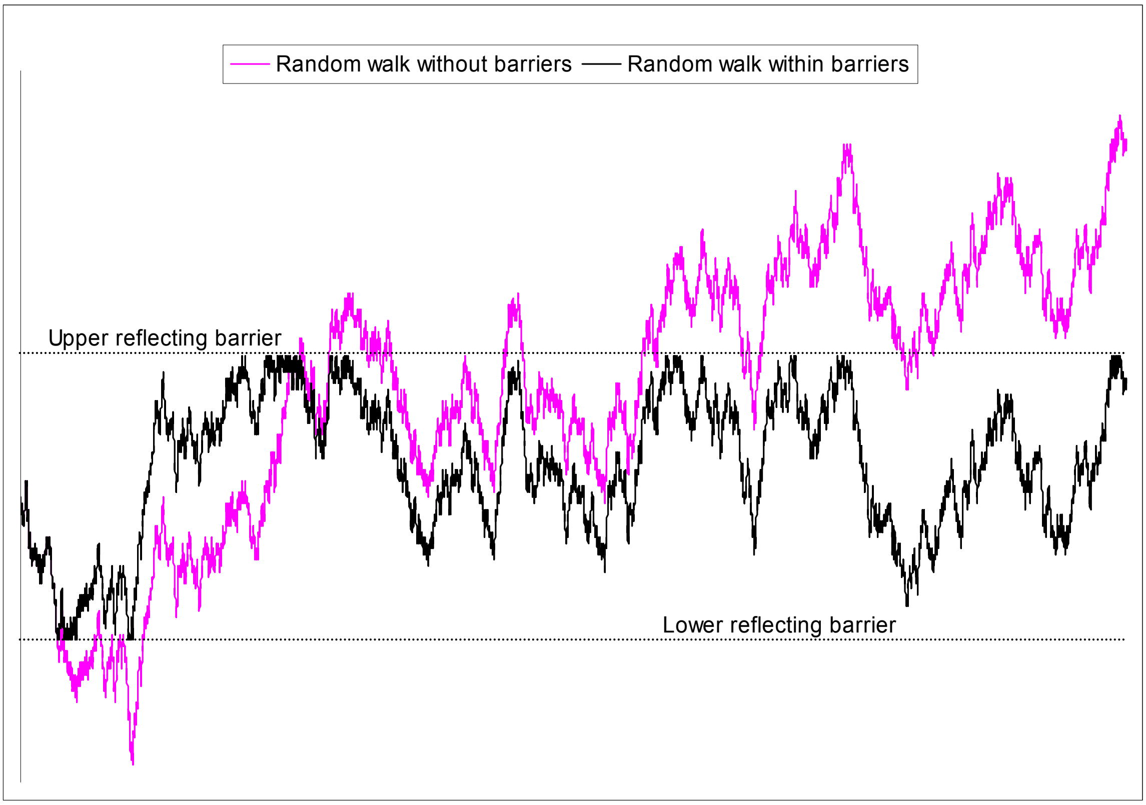

Fig. 1

Random walk with and without reflecting barriers

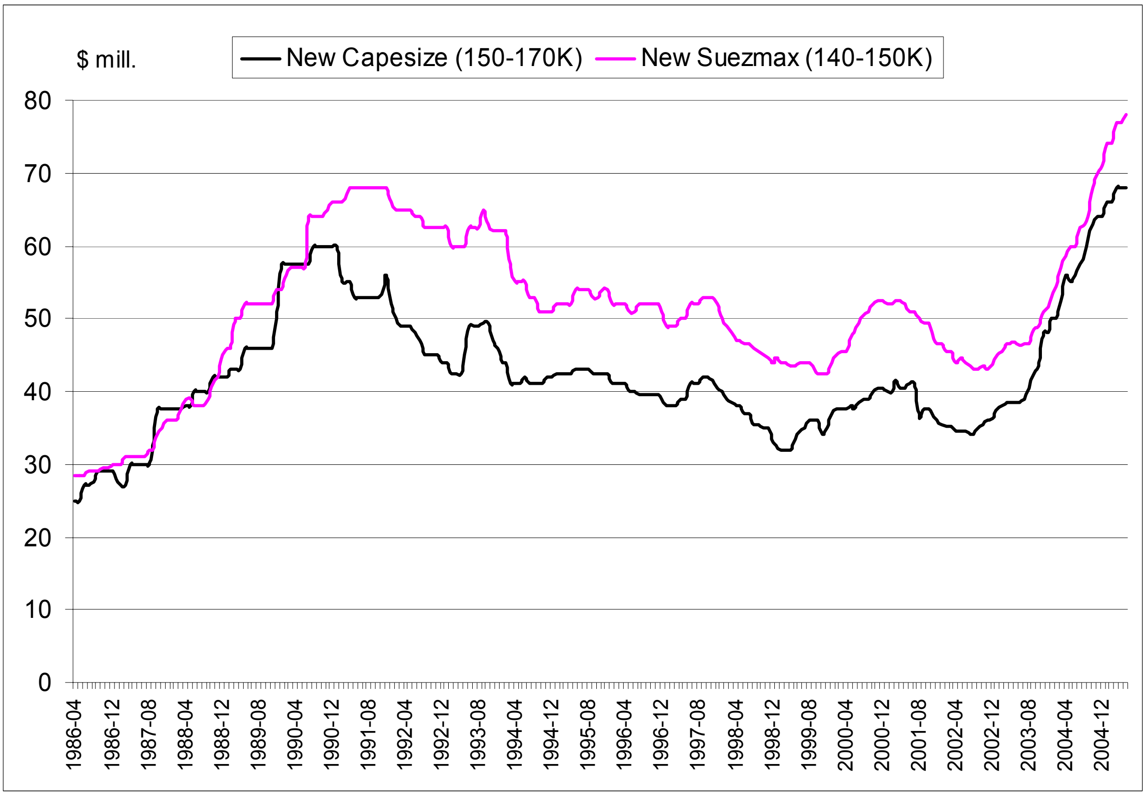

Fig. 2

Newbuilding prices in the bulk ship market (Clarksons, 2005)

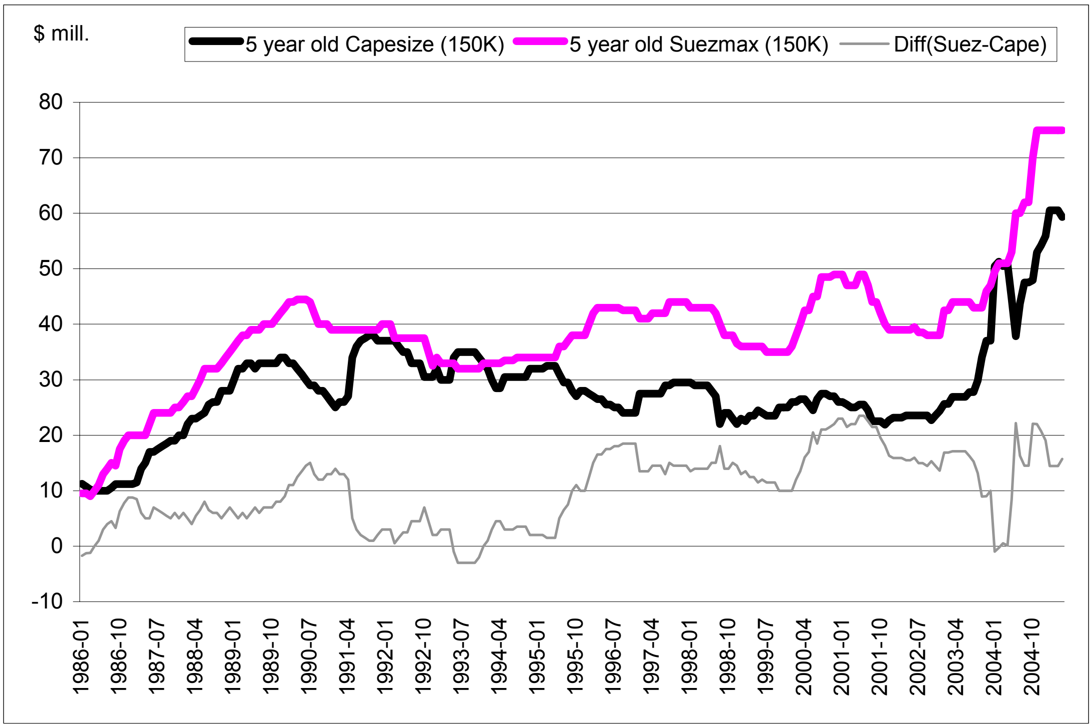

Fig. 3

Secondhand prices in the bulk ship market (Clarksons, 2005)

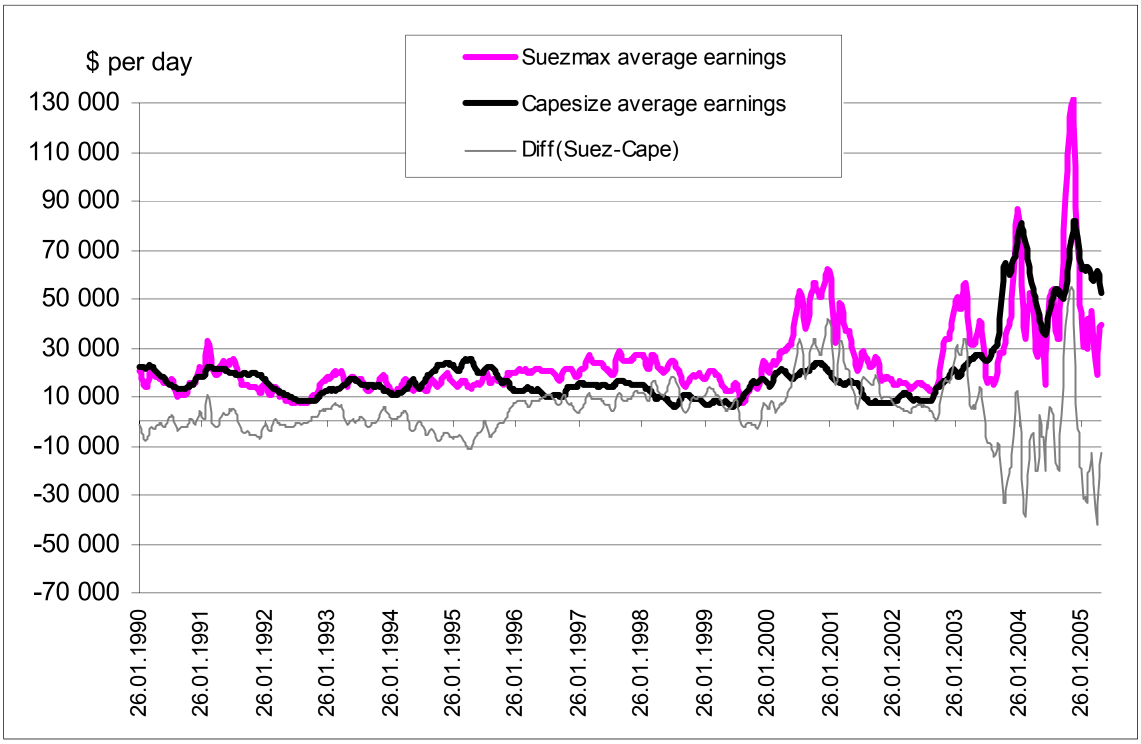

Fig. 4

Freight rates in the bulk market (Clarksons, 2005)

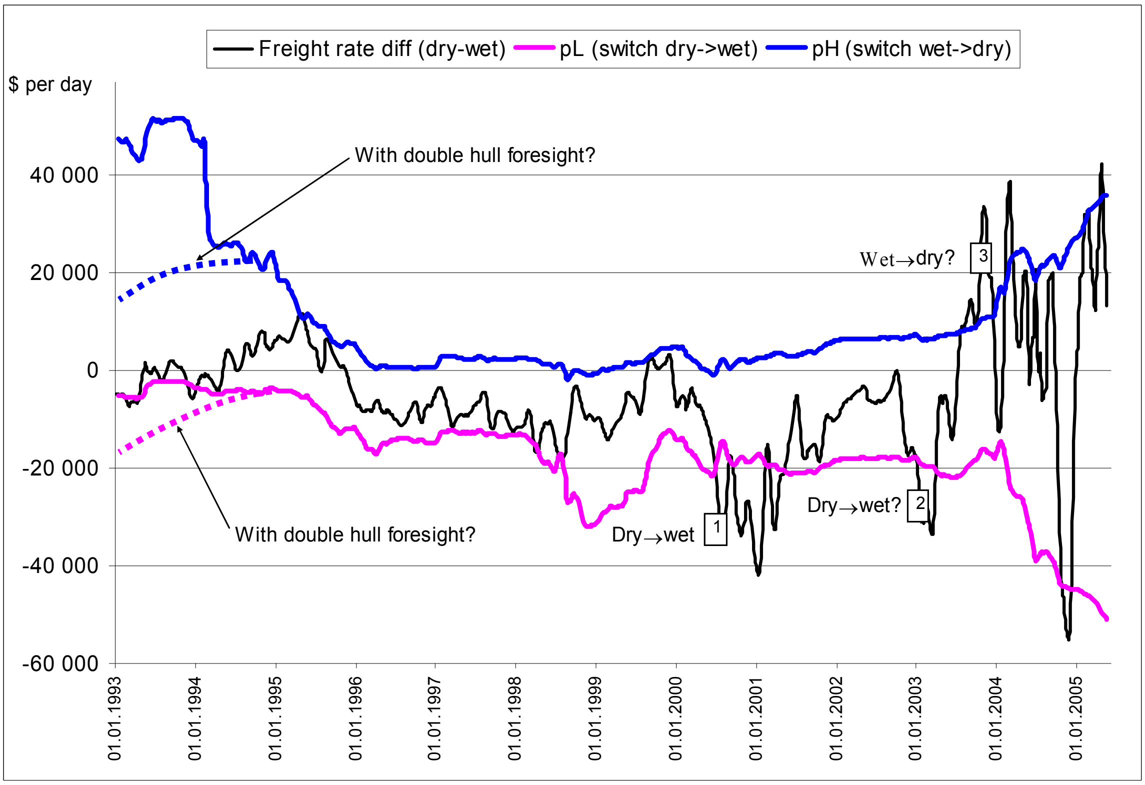

Fig. 5

Freight rate differentials and optimal switching barriers in the bulk market

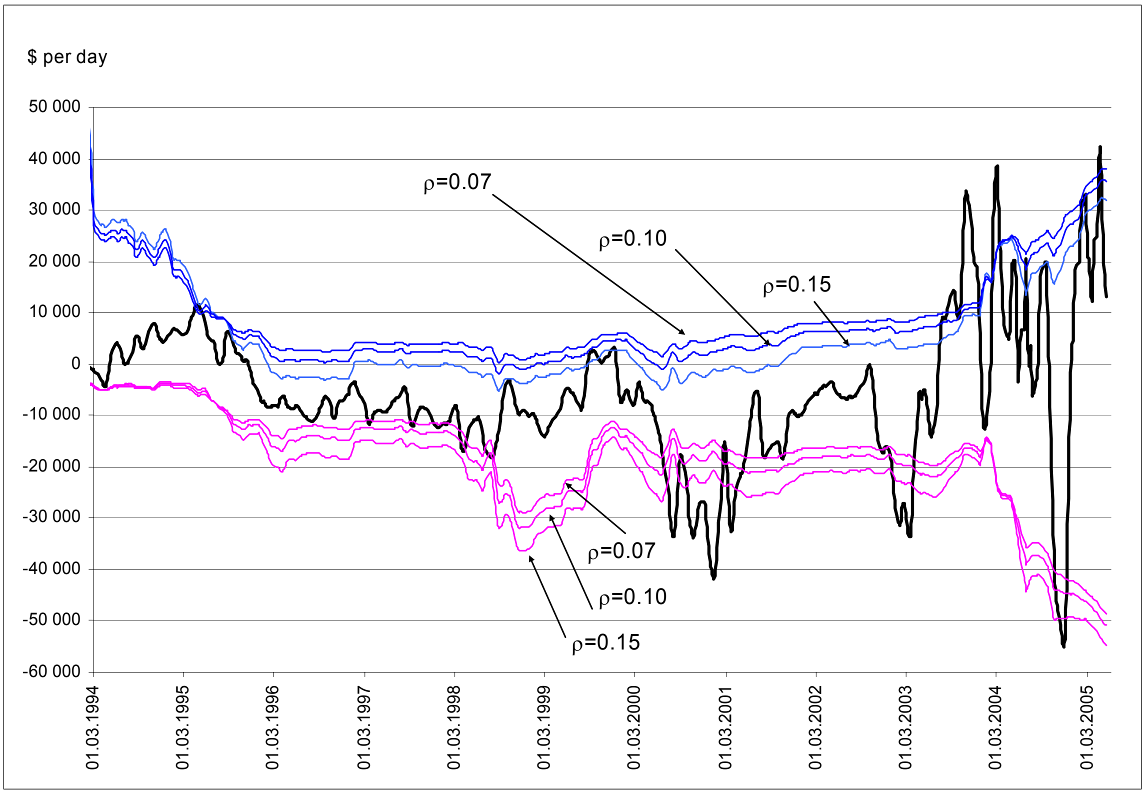

Fig. 6

Optimal switching barriers under various discount rates

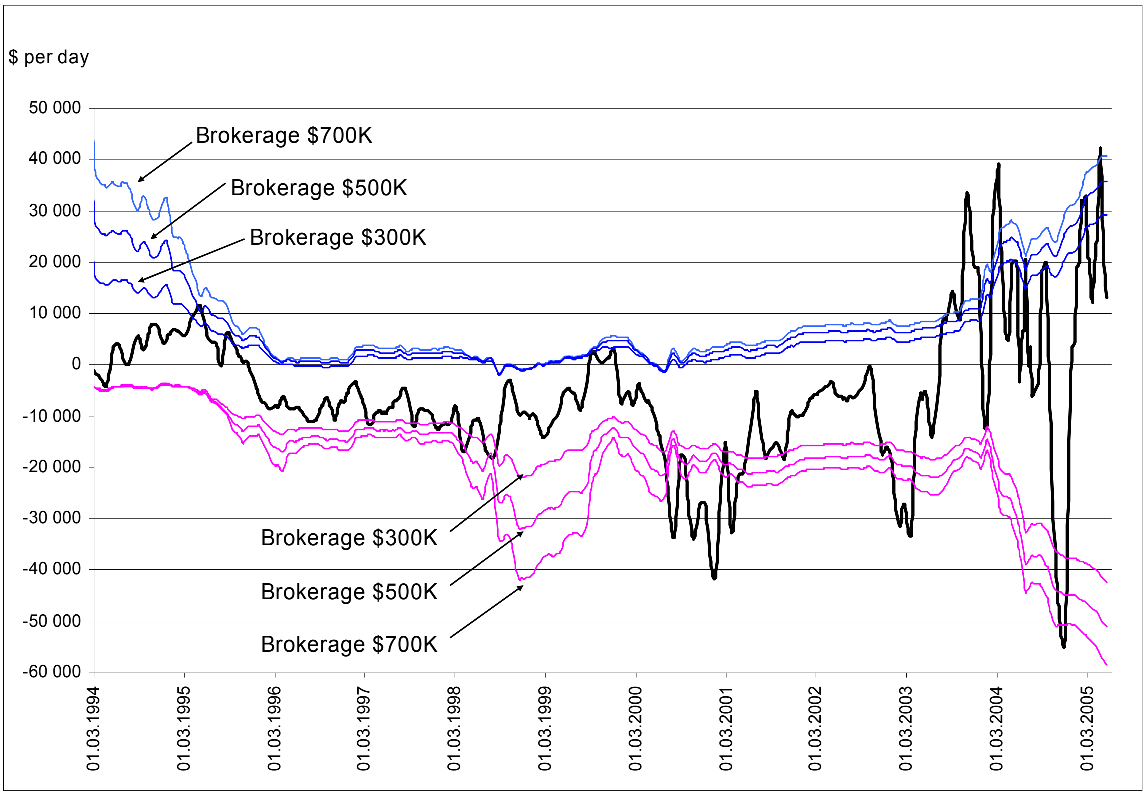

Fig. 7

Optimal switching barriers under various switching costs