Simulating physical basis risks in the Capesize freight market

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Abstract

The purpose of this paper is to evaluate the characteristics of the time-varying differential between the Baltic global tripcharter average and simulated earnings from a fleet of Capesize vessels. We interpret the standard deviation of this differential as a measure of physical basis risk in freight market hedging, resulting from differences in assumed trading patterns and the sequential fixing of vessels at different regional rates around the world. We simulate the average earnings of a fleet over time by sequentially assigning vessels to any of the four main trading routes (trans-Atlantic, trans-Pacific, fronthaul and backhaul) with a conditional probability based on known historical commodity flows. We show that increasing the fleet size lowers basis risk but that this diversification effect is low beyond a relatively small fleet size of about 10 ships. Furthermore, we show that this physical basis risk never disappears, even for a very large fleet, due to a moving-average effect in earnings. Finally, we illustrate that physical basis risk is greater for short hedging durations. The results are important for shipowners and operators in the design of cost-efficient hedging programmes and for the Baltic Exchange and its stakeholders engaged in the continuous improvement of the quality of its spot rate indices.

Keywords: Hedging; spot freight rates; FFA; drybulk; basis risk, earnings simulation

Introduction

Having representative spot price indices for the settlement of derivatives is key to the success of any derivatives market. The BIFFEX freight futures ceased trading in 2002 ostensibly because the underlying BFI index was too broad based and therefore unsuitable for hedging purposes (Kavussanos and Visvikis, 2006). Specifically, the BFI was calculated as the weighted average of freight rates across 11 shipping routes and vessel sizes (see e.g. Kavussanos and Nomikos, 2003, for details on composition) causing it to be a poor proxy for individual routes. The Forward Freight Agreements (FFAs) that took over from the mid-1990s (see, e.g. Kavussanos and Visvikis, 2004a, 2004b) were primarily settled against the spot rates for individual voyages. However, liquidity for these voyage-based contracts have since largely disappeared as drybulk FFA traders have turned to contracts settled based on the global composite timecharter (TC) rates by ship size (e.g. the Capesize 4TC average and Panamax 4TC average, see Baltic Exchange, 2015, for details). This development follows the the physical spot freight market, where charterers have increasingly turned to tripcharter contracts due to their inherent greater flexibility with regards to cargo size, routing and the avoidance of demurrage problems. We note the trade-off between having broad composite spot indices and highly specific voyage-based contracts. Spot rate indices that relate to specific voyages offer improved hedging efficiency on these routes, but risk dividing market liquidity. Conversely, spot rate indices that represent global averages of vessel earnings will concentrate market liquidity, but will by definition follow individual regional routes less closely and therefore offer reduced efficiency for short-term hedging. Keeping with the above changes, physical operators today will hedge their freight market exposure on a fleet-wide basis using longer-term (e.g. calendar year) contracts settled against the global composite TC averages by ship size. If the hedge remains in place through settlement, the traditional financial basis risk will by definition have resolved itself as the FFA price will converge throughout the delivery month to the arithmetic average of the spot rate. Hence, what matters for the performance of these hedges is not the short-term co-variation between spot and FFA prices but rather the mismatch between the income stream of your physical fleet and the relevant spot rate index. In the remainder of this paper we denote the standard deviation of this earnings differential as the “physical basis risk”.

Physical basis risks have not yet been investigated in the maritime economics literature and our paper seeks to fill this gap. Specifically, the contribution of this paper is threefold: Firstly, we evaluate qualitatively the various sources physical basis risks in the freight market. Secondly, we show on the basis of a new simulation methodology how physical basis risk is reduced (but does not disappear) when the fleet size is increasing, similar to a portfolio diversification effect. Thirdly, we illustrate how the impact of physical basis risk is reduced with hedging duration.

Our findings are important for several agents in the shipping industry. Firstly, they can guide shipowners, charterers and operators that are actively hedging their freight market exposure in the design of more efficient hedging programmes in terms of contract duration and realised trading patterns. Secondly, they serve as a reminder to shipping investors that "big need not be better" in the sense that big diversified fleets do not offer a reduction in earnings risk compared with mid-size drybulk fleets. Finally, they serve as important input to ongoing efforts within the Baltic Exchange to revise and update the composition of routes in an attempt to keep up with changes in the trading pattern of the global drybulk. This is reflected the occasional launch of new routes, the suspension of old routes that are no longer used, as well as changes in weightings between routes (Baltic Exchange, 2015). We show, for the first time, what the impact of such deviations between the real trading patterns and assumed route weightings actually lead to in terms of increasing physical basis risk.

The remainder of this paper is structured as follows: We first review the relevant literature on the freight derivatives market. We proceed to describe the various sources of physical basis risks in freight market hedging and the data and methodology behind our simulations of vessel earnings. Finally, we show the results of the simulations and present our concluding remarks.

Literature review

The spot freight rate is the price of a service that cannot be stored or traded by investors, and so there is no mathematical relationship based on the cost of carry that defines the relationship between spot and forward rates. Instead, forward freight rates are based on market expectations and a potentially time-varying risk premium (see, Adland and Cullinane, 2005, for a thorough discussion). Freight is therefore a very interesting special case where, for instance, it should be expected *a priori* that freight derivatives provide poor hedging efficiency in comparison to other commodity and financial markets.

It is not a surprise, then, that a considerable amount of empirical research has been directed towards examining the relationship between spot freight rates and freight derivative prices, as well as the related price discovery function and hedging efficiency. For instance, Thuong and Visscher (1990) use the Minimum Variance Hedge Ratio (MVHR) to estimate the hedging efficiency of the BIFFEX freight futures contract and conclude that it is substantially lower than for other commodity markets. Haralambides (1992) compares the hedging efficiency from using a naive (on-to-one) hedge with that of the MVHR and concludes that the latter leads to some improvement in efficiency. Kavussanos and Nomikos (1999) investigate the unbiasedness hypothesis of futures prices in the BIFFEX freight futures market in a co-integration framework and conclude that futures prices one and two months before maturity are unbiased forecasts of the realized spot prices, whereas a bias exists in the three-month futures prices. Kavussanos and Nomikos (2000a) examine the hedging characteristics of the BIFFEX contract within a GARCH framework that takes account of co-integration between the spot and futures markets. They find that allowing for time variation in the hedge ratio improves hedge performance, but basis risk remains very large compared with other futures markets. Kavussanos and Nomikos (2000b) compare the hedging performance of constant vs. time-varying hedge ratios and hedging efficiency in the BIFFEX market. Their in- and out-of-sample tests reveal that a GARCH-X specification provides greater risk reduction than a simple GARCH and a constant hedge ratio, but fails to eliminate the riskiness of the spot position to the extent evidenced in other markets. In related work, Kavussanos and Nomikos (2000c) demonstrate that, while low compared to other commodity markets, the hedging effectiveness of the BIFFEX contract improved over time in line with revisions of the structure of the underlying index. Kavussanos and Nomikos (2003) find that BIFFEX freight futures prices discovered information more rapidly than spot prices and produced more accurate forecasts of spot prices than standard timeseries models. Haigh et al (2004) investigate the contemporaneous correlations between the different routes of the Baltic Panamax index (BPI), the successor to the BFI, and argue that the index was not appropriately composed and weighted.

Following the introduction of FFAs in 1992, a similar plethora of empirical studies investigated the hedging performance, price discovery function and causality viz-a-viz spot freight rates (see, Kavussanos et al, 2004a; 2004b; Kavussanos and Visvikis, 2004). The results are similar to the earlier studies on the defunct BIFFEX market, indicating overall poor hedging efficiency and unbiased forecasts only in the short run (1 – 2 months out). The above studies are based on OTC prices for individual routes ($/tonne basis) in the Panamax drybulk segment in the early years of the FFA market. More recent research on freight derivatives, such as Kavussanos and Visvikis (2010), Goulas and Skiadopoulos (2012), investigate hedging efficiency for timecharter-based ($/day) FFA contracts, albeit still with a short-term view of hedging.

Physical basis risks in shipping

In this section we elaborate on the most important sources of physical basis risk in the freight markets, that is, what are the main sources of deviation between the revenue stream being hedged (that is, actual timecharter-equivalent earnings from one or more ships) and the spot rate process underlying the settlement of the hedging instrument?

Technical specifications

Any deviations in the technical specifications of the vessel compared to the standard Baltic-type assumptions (see, Baltic Exchange, 2015, for details) will be a cause of physical basis risk. The main driver here is the cargo-carrying capacity, or deadweight (DWT), of a given vessel. For instance, while the standard “Baltic type” Capesize vessel is defined as a vessel of 172,000 DWT, this size segment covers a very wide range of vessel sizes and technical specifications from small 115,000 DWT mini-Capes to giant 400,000 DWT Valemax behemoths. However, other micro-economic factors such as age also influence freight rates, according to studies by Alizadeh and Talley (2011a, 2011b).

Actual operating speed and fuel consumption

Real-life deviations in operating speeds and fuel consumption compared to assumptions underlying the Baltic Exchange route definitions will be a cause of basis risk[1] as fuel costs are a substantial part of earnings calculations. Maritime economic theory (see, e.g. Strandenes, 1999, Devanney, 2010) suggests that ships should reduce speeds in times of low ($/tonne) freight rates and high fuel prices – so-called slow-steaming – and that the theoretical optimal speed depends on the ratio between the spot rate and the fuel price, at least in a one-period setting. While empirical studies largely confirm that slow-steaming takes place in challenging markets (see, e.g. Smith et al., 2013), the results generally do not support the assertion that shipowners dynamically optimise speeds (Adland, 2013). Instead, charterparty clauses referring to "utmost dispatch", competition for cargo, technical engine limitations or organizational barriers (such as knowledge about engine operation at low rating) will often guide the vessel speed choice in practice.

Geographical trading pattern

The geographical trading pattern for large drybulk vessels is customarily divided into four main routes: trans-Atlantic (TA), trans-Pacific (TP), Fronthaul (FH) trips from the Atlantic to the Pacific basin, and backhaul (BH) trips from the Pacific to the Atlantic. We note that trans-Atlantic trips need not cross the Atlantic at all but could also include, for instance, short trips between continental Europe and Baltic/Russian loading ports. Similarly, return trips between India and South Africa (loading) are here classified as trans-Pacific even though most geographers would consider the Indian Ocean separately. The Baltic Exchange tracks the tripcharter rate for each of these separately and calculates the 4TC average spot index underlying the FFA contracts as the arithmetic average. Basis risk will arise here because the real-life trading pattern of the global fleet is not equally weighted but rather skewed towards Asian destinations. Figure 1 below shows the changes in the estimated monthly market share of the four main trading routes since January 1999.

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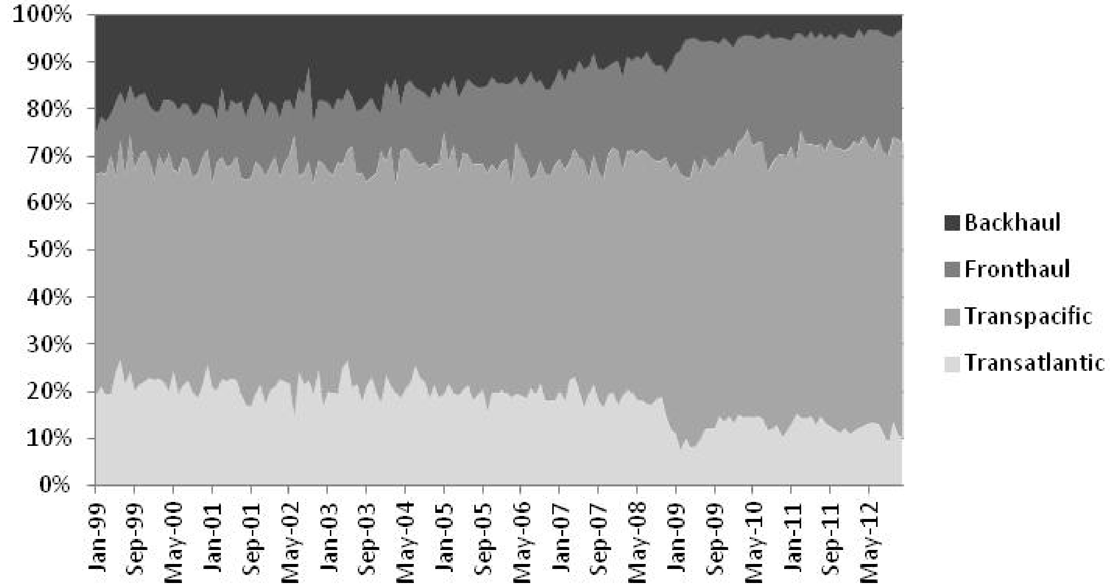
[1] On 12 June 2013 the assumed speed speed of a Baltic Capesize ship for the timecharter indexes published by the Baltic Exchange was changed from 14.5 (15) knots in laden (ballast) condition on a fuel consumption of 56 tonnes/day to 12 (13) knots in laden (ballast) condition on a fuel consumption of 44 tonnes/day. Our empirical work relates to assumptions in place prior to 12 June 2013.

Figure 1 – Market share of the four main trading routes for Capesize vessels



Source: Thurlestone Shipping Ltd., Research department

Timing mismatch

Physical basis risks due to timing mismatch here refers to the fact that FFAs are settled against the arithmetic average of the spot rate of every UK business day in a month, while physical fixtures can occur on any single day and generally relate to trips that will commence in the future. Once a ship is fixed and the trip has commenced, the vessel will then obtain a fixed rate for the entire duration of the trip until redelivery, typically anywhere from three weeks to three months for big drybulk vessels. Depending on the volatility of the underlying market this mismatch can have a large effect on the performance of the hedge (Alizadeh and Nomikos, 2009). Within this area we can also add the basis risk stemming from differences between the duration of actual trips and the definitions of the standard trips underlying the Baltic Exchange freight rate indices (ref. Table 1 below). Such differences will arise because of, for instance, port congestion, delays in loading or discharge, and unusual geographical routing.

Vessel unemployment

A ship that is not under a paid contract will contribute to a differential in earnings between the spot index and the cash flow from fleet operation. The reasons could be technical off hire due to breakdowns, temporary idleness while waiting for the next contract, repositioning the vessel for the owner's account, or longer-term cold lay-up during distressed freight market conditions.

Simulation methodology

For the time being there are no realistic alternatives to simulations in assessing the impact of basis risk on a fleet-wide hedging programme. This is because we do not have anywhere near full information on either the freight rates obtained by individual ships or their complete trading pattern. Only a fraction of fixtures publicly reveal the freight rate at which the vessel was chartered, and charterers frequently perform voyages using their own or timechartered tonnage for which there would be no public assessment of internal pricing. Moreover, while substantial progress has been made in the real-time tracking of the global fleet using the Automated Identification System (AIS), such position data has only been collected for a few years and even today has incomplete coverage.

Accordingly, while there are numerous sources of basis risk as detailed in the section above, data availability will limit the complexity of our modelling in practice. Specifically, we do not yet have access to complete and ship-specific data on vessel speed, fuel consumption, actual routing, idleness or layup and so these sources are beyond the scope of our study. However, we do have aggregate data on cargo flows as per Figure 1 above, as well as the typical ranges of trip durations as per Table 1. This enables us to assess the impact of geographical trading patterns and timing mismatch as sources of basis risk. It is not possible to separate the time and geographical effects without reducing the realism of the simulations, and so we consider their joint impact on the difference between realised average earnings from physical operation and the spot index used for settlement in the FFA market (i.e. the 4TC average). We focus on the Capesize fleet as its trading pattern is substantially less complex than that for the smaller sizes due to the fewer number of ports that can serve these vessels as well as the limited types of cargo they carry (principally only coal and iron ore). Given that freight rates for Capesize vessels are known to be more volatile than those for smaller vessels (Kavussanos, 1996), larger regional rate differences will also translate into greater basis risk, thus making this the most interesting empirical case.

The purpose of our simulation model is to simulate a realistic trading pattern for a single vessel or fleet of vessels over time. While the number of permutations between port pairs is substantial even in the Capesize segment, we here restrict the outcomes to the four tripcharter routes as defined by the Baltic Exchange[2] and summarised in Table 1 below. Accordingly, a ship open in the China/Japan range may only fix on another trans-Pacific voyage or a (paid) backhaul voyage, and not speculatively reposition to the Atlantic. Conversely, a ship open in the Amsterdam/Rotterdam/Antwerp (ARA) range may only be fixed on a Transatlantic or a Fronthaul trip.

Table 1 – Tripcharter routes included in the Capesize 4 TC average spot index

Baltic route	**Delivery range**	**Redelivery range**	**Route**	**Duration (days)**
C8_03	Gibraltar/Hamburg	Gibraltar/Hamburg	Transatlantic	30-40
C9_03	Amsterdam/Rotterdam/Antwerp	China/Japan	Fronthaul	60-70*
C10_03	China/Japan	China/Japan	Transpacific	30-40
C11_03	China/Japan	Amsterdam/Rotterdam/Antwerp	Backhaul	60-70*

* The Baltic Exchange manual states duration as “around 65 days” but we use a range for the sake of consistency compared to TA and TP trips in the simulations

In order for our simulated trading pattern to converge, on average, to the historical trading pattern observed in the past the conditional probability of a vessel being assigned to a route must be given by a ratio of the aggregate cargo volumes underlying the market shares depicted in

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[2] This paper uses the Baltic Exchange assumptions in place prior to the latest revision of the Baltic Exchange Capesize indices on 5th May 2014.

Figure 1. Formally, if we denote the Capesize cargo volume for a given main route as $Y_{i,j}$ where i = TA, TP, FH and BH, respectively and j denotes time (calendar month basis), then the probability of fixing a vessel on a trip, conditional on the vessel being fixed at time j and starting in the Atlantic (A) or Pacific (P) can be written as:

$$P_j(TA|\mathrm{A}) = \frac{\mathrm{Y}_{\mathrm{TA,j}}}{\mathrm{Y}_{\mathrm{TA,j}}+\mathrm{Y}_{\mathrm{FH,j}}} \tag{1}$$

$$P_j(FH|\mathrm{A}) = \frac{\mathrm{Y}_{\mathrm{FH,j}}}{\mathrm{Y}_{\mathrm{TA,j}}+\mathrm{Y}_{\mathrm{FH,j}}} \tag{2}$$

$$P_j(TP|\mathrm{P}) = \frac{\mathrm{Y}_{\mathrm{TP}}}{\mathrm{Y}_{\mathrm{TP,j}}+\mathrm{Y}_{\mathrm{BH,j}}} \tag{3}$$

$$P_j(BH|\mathrm{P}) = \frac{\mathrm{Y}_{\mathrm{BH}}}{\mathrm{Y}_{\mathrm{TP,j}}+\mathrm{Y}_{\mathrm{BH,j}}} \tag{4}$$

As an example, if a ship was open in North Asia during a month where 90mt of cargo was shipped on the trans-Pacific trade and 10mt was shipped on the backhaul trade, the probability of being assigned to the TP route is 90/(90+19) = 90%. Given the conditional probabilities above, the simulation is implemented using macros in Excel as follows:

- At time j = 0, assign a vessel randomly to Atlantic or the Pacific, such that the fleet achieves a steady geographical state quicker.
- For any subsequent time j when a vessel has finished a voyage, assign it to one out of the two possible trip alternatives based on whether she is currently open in the Atlantic or Pacific. This is implemented based on whether a uniformly distributed random variable $z \in [0, 1]$ exceeds the calculated conditional probability level.
- Draw the trip duration as a random integer from the range in Table 1. We assume that all voyages are undertaken on a consecutive basis without any idleness.
- Find the prevailing tripcharter rate for the fixture time j using Baltic Exchange data. If the vessel becomes open (completes discharge) on a weekend or public holiday, it is assumed to be fixed at the last reported rate.

The Baltic Exchange dataset contains 2,872 daily freight rate observations for each of the four main routes for every UK working day in the period May 1st, 2002, through 7th May 2014. When we simulate more than one ship the appropriate earnings measure for the purposes of fleet-wide hedging is the average daily earnings from the entire fleet (i.e. the average of all ongoing tripcharters).

Simulation results

The results presented below relate to a standard "Baltic type" vessel operating at the Baltic standard speed. We note first that while the stream of earnings from a single vessel is a discontinuous step function, representing changes in the freight rate at random fixture dates, the simulated average daily earnings from a fleet will gradually get a smoother appearance as the number of ships in the fleet increases. This is clearly illustrated in Figure 2 below which contains two paths of simulated average earnings for one and 10 ships, respectively, for the period January 2011 to May 2014.

Figure 2 – Simulated average daily earnings for different fleet sizes

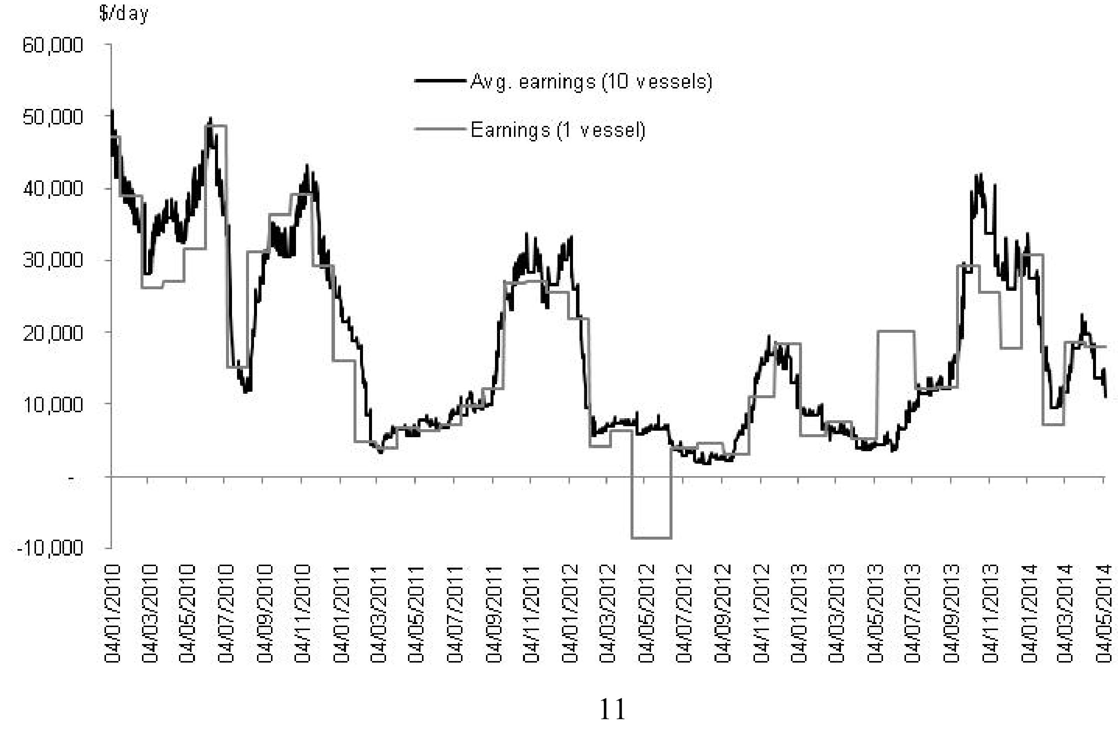
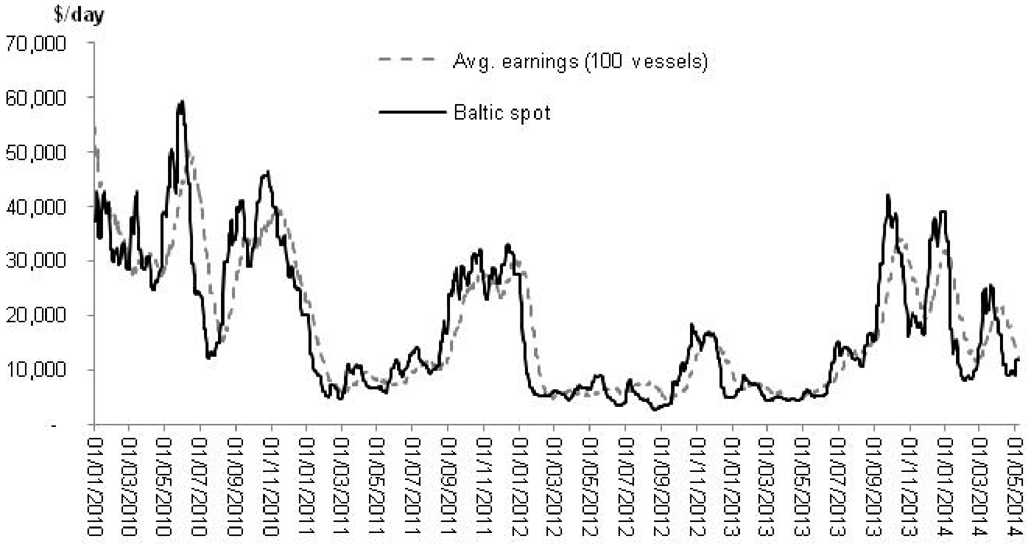


Figure 3 illustrates the observed smoothing and "lag effect" in physical earnings compared to the Baltic 4TC average spot index. Given that the daily earnings from one vessel remain constant throughout each trip, the average daily earnings from a large fleet must reflect the moving average of past spot rates over a period equivalent to the (potentially time-varying) average duration of all ongoing trips. This "smoothing" effect is clearly visible in the graph.

Figure 3 – Simulated daily average earnings (100 vessel fleet) vs. Baltic 4TC average index



To further illustrate the above important point, Table 2 shows the standard deviation of the realized physical basis risk as a function of contract length for one and 10 vessels respectively. The basis risk is measured as the deviation (in $/day terms) between the simulated fleet earnings and the realized Baltic 4TC Capesize average. The descriptive statistics are based on simulated fleet earnings for the calendar year 2013 using 1000 paths for each data point. A priori we would expect that short contracts are subject to greater physical basis risk than longer contracts, mainly due to the geographical diversification of trading patterns that will necessarily occur over the course over a year, say, compared to a single quarter. Over a short timespan there is a greater risk that a small fleet of vessels will trade only on a small subset of geographical routes and, as a result, realise earnings that are less correlated to the global average represented by the Baltic index. Indeed, our simulations underpin this hypothesis, with declining standard deviation of basis risk both with increasing fleet size and increasing contract length.

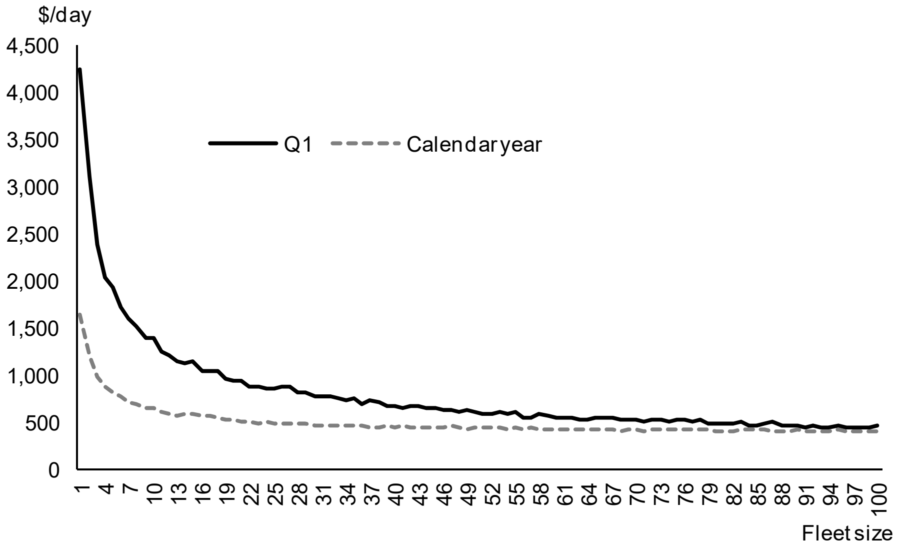
Table 2 – Descriptive statistics of simulated earnings differential

	1 vessel				10 vessels			
	Q1	Q1+Q2	Q1+Q2+Q3	Full year	Q1	Q1+Q2	Q1+Q2+Q3	Full year
Mean ($/day)	718	260	-1325	-1423	856	396	-1253	-1365
Std. dev. ($/day)	4246	2909	2046	1640	1396	947	661	642
Kurtosis	2.41	0.85	0.68	0.52	0.87	0.24	0.31	8.50
Skewness	0.04	-0.27	-0.32	0.33	0.10	-0.11	0.02	1.48
5th percentile ($/day)	-8884	-5967	-5430	-4057	-1411	-1147	-2348	-2294
95th percentile ($/day)	9239	5651	2321	1654	3118	1844	-171	-426
Actual spot avg. ($/day)	6020	6141	10466	14432	6020	6141	10466	14432

The table refers to the distribution of simulated earning differentials for the year 2013 using 1,000 paths.

Figure 4 shows the rapid diversification effect for relatively small fleet sizes in more detail. Indeed, we can see that even 3-4 ships delivers a substantial reduction in physical basis risks compared to the single-ship case, and that increases in fleet size beyond 10 ships does not lead to any significant further reductions as long as the hedging horizon is a year or longer.

Figure 4 - Standard deviation of differential between simulated earnings and Baltic index



However, for a relatively short hedging horizon of a single quarter, increasing fleet size matters more as a compensation for a potentially unbalanced geographical trading pattern in the very short run. Figure 4 also clearly show how the physical basis risk never disappears even for very large fleets – it merely converges to a level that will be dependent on the underlying volatility of freight rates in the market (ref. the smoothing effect discussed above). Nevertheless, Figure 4 illustrates how a medium-sized shipowner hedging his fleet's earnings using long-term FFA contracts (a calendar year) is able to reduce the physical basis risk in his hedging programme to acceptable levels, with a standard deviation of only $500/day relative to realized average spot rates of $14,432/day in our 2013 example.

Concluding remarks

This paper is a first attempt at quantifying physical basis risk in freight market hedging. We have shown that differences in real-life trading patterns compared to the assumptions underlying the Baltic Exchange spot rate indices can generate substantial differentials in average earnings, particularly over short horizons. We have also shown that there exists a lag-effect in physical earnings compared to the spot index that results from the long duration and fixed rate of each trip, and this lag effect reduces the degree of co-variation between spot and physical earnings. While the effect of this mismatch can be reduced by increasing the fleet size, leading to diversification in geography and time, we show that there is limited utility in doing so beyond about ten vessels for a one-year hedging horizon.

We note that physical basis risk is likely to be of greater magnitude in the Capesize segment than for smaller vessel sizes. Firstly, though not explicitly considered in this study, vessel size dispersion is substantially greater for Capesizes than for Handymax/Supramax (40,000 – 60,000 DWT) and Panamax vessels (60,000 – 100,000 DWT). Secondly, freight rate volatility for smaller vessels tend to be lower than for larger vessels (Kavussanos, 1996) suggesting that regional differences will also be smaller. Thirdly, smaller vessels tend to trade on shorter routes which will by definition reduce the lag effect discussed above. Finally, at least in the case of the Supramax market, the Baltic timecharter average represents the weighted average of 6 regional routes and this wider geographical coverage should also contribute to reduced deviations between the Baltic index and real-life vessel earnings.

Future research should extend the above analysis also to smaller vessel sizes and tankers, as well as to include the impact of idleness and changes in actual speeds. However, this will only be a realistic option once detailed and reliable AIS data become commonplace. Nevertheless, we believe that this article opens up an exciting avenue for further research in the cross section between physical ship operation and financial risk management.

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