The use of freight rate options and pricing implications

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Agenda

1. **A primer on options**
2. **Risk management strategies using freight rate options**
3. **Option-trading strategies**
4. **Pricing freight rate options**
5. **A look at real-world freight rate options data**

A primer on freight rate options (1)

- **Call option:** Contract that gives its holder (or buyer) the right, but not the obligation, to buy an **underlying asset** (such as a **freight rate**) from the seller (or writer) of the call option at a certain price (the strike price or exercise price) at a certain point in time (the expiration date or maturity).

- **Put option:** Contract that provides its holder with the right, but not the obligation, to sell an underlying asset to the writer of the put option at a certain strike price at the expiration date.

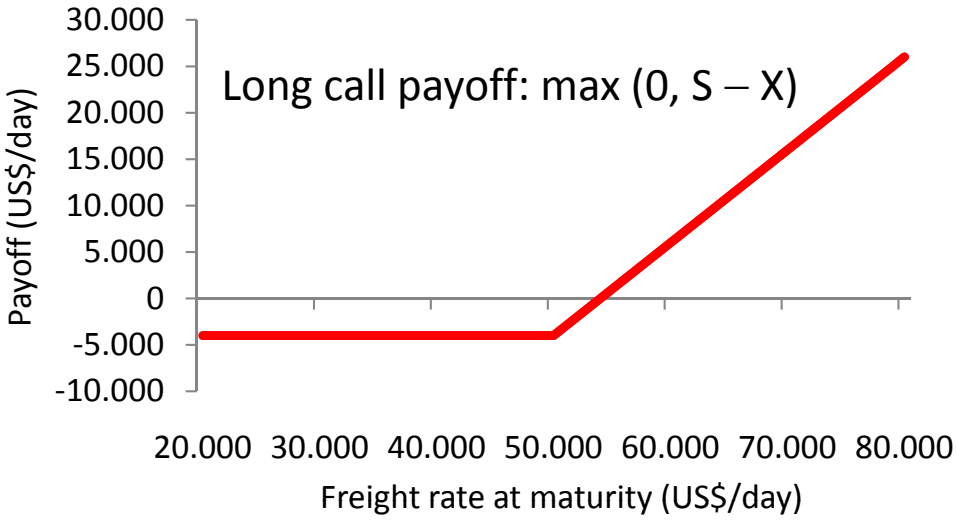
- A **European option** can only be exercised at the maturity of the option. In contrast, an **American option** can be exercised at any time during the option's life, including the maturity. Freight options are European-style options.

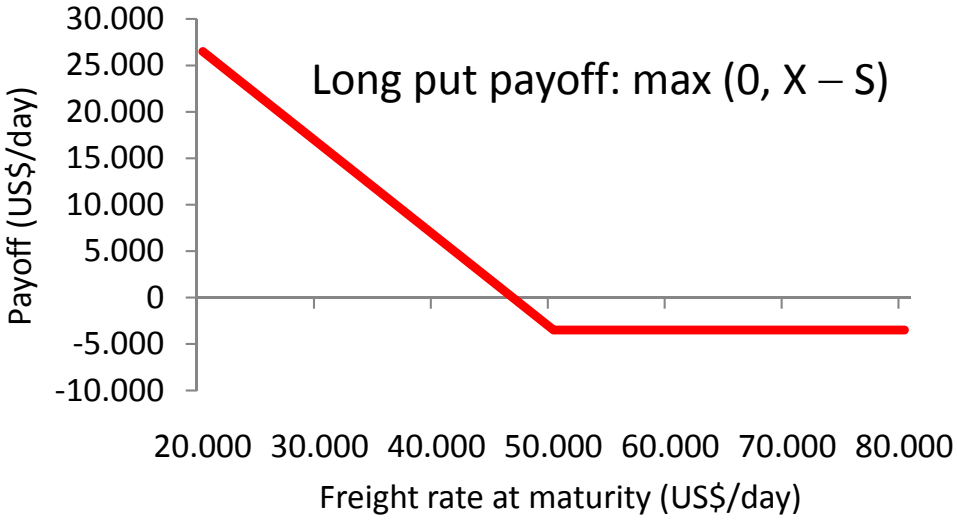
- The option holder is under no obligation to settle the contract (**non-linear** contract); this is in contrast to a futures or forwards contract (**linear** contract).

A primer on freight rate options (2)

- A simple example: Consider a BPI 4TC Q3+Q4 2008 **call option** with a strike price of US$ 50.000 (i.e., the underlying is the Baltic Panamax Index) .
  - The contract is a **strip of six options** for each of the six months in Q3 and Q4 of the year 2008. Each option will be settled separately at the end of a month and the settlement rate will be calculated as the average BPI 4TC rate in that month.
  - The option buyer has the right, but not the obligation, to buy (settle) the freight rate for BPI 4TC at the end of any of the six months during Q3 and Q4 as the difference between the strike price and the average BPI 4TC rate in that month.
  - If the average BPI 4TC rate in any month is US$ 60.000, the buyer of the option will exercise the option and receive US$ 10.000/day. In contrast, if the average BPI 4TC rate is only US$ 45.000, the option holder will let the option expire worthless.
  - The option buyer has to pay the **premium** of US$ 4.000/day upfront. The total premium payable within five business days is US$ 736.000 ($=$ US$ 4.000 $\times$ 184).

Payoffs at maturity and factors affecting option values





Effects on the price of European options

	European call	European Put
Asset price (S)	+	–
Strike price (X)	–	+
Maturity	+	+
Volatility	+	+
Risk-free rate	+	–

Note: Payoffs are shown at the end of each month. Short positions on call and put options are not shown here.

Practicalities of trading options in the freight market

- Freight rate options are traded in a similar way the underlying FFA contracts are transacted; they are settled in cash and there is **no physical shipment** involved.
- Buyers and seller of options agree on a strike price and negotiate a premium.
- The premium is quoted in US$/day for time charter routes, in US$/ton for voyage charter routes, and in WS points for tanker routes.
- The calculation of the **settlement price** differs with the type of the contract:
  - Settlement rate as the average freight rate of the month applies for most contracts.
  - Settlement rate as the average freight rate of the last seven trading days applies for certain contracts (such as P2A and P3A).
- Options are usually traded between two counterparties through a broker, either as an over-the-counter (OTC) contract or through a clearing house. Freight options on certain routes are also available for trading on hybrid exchanges.

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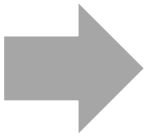
Risk management strategies using freight options (1)

- A **shipowner** who wants to protect his freight income against a future decline in freight rates will **buy put options.**
  - The shipowner is long in freight, and hence the risk is that freight rates may fall.
  - He does not want his freight income in any of the months to fall below US$ 50.000/ day, and therefore he buys a BPI 4TC Q3+Q4 2008 **put option** with a strike price of US$ 50.000, paying a US$ 3.500/day premium.
  - If the average BPI 4TC rate in the market is below the strike price of US$ 50.000/day in any of the six months, the put option will be exercised; the owner created a floor of US$ 46.500/day (= US$ 50.000 /day – US$ 3.500/day).
  - If the average BPI 4TC rate in the market increases above US$ 50.000/day in any of the six months, the owner will be able to take advantage of the higher freight rates in the market, and hence the put option will expire worthless.

⇒ The shipowner buys an **insurance** against declining freight rates.

Risk management strategies using freight options (2)

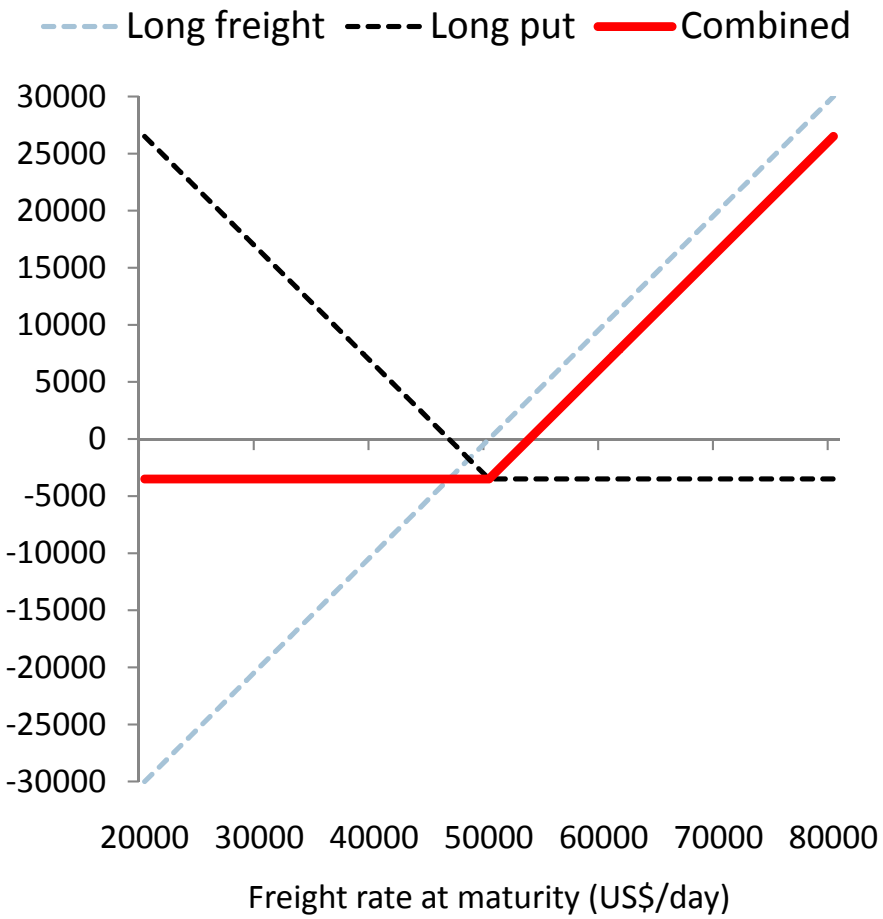
- A **charterer** who wants to protect his freight costs against a future increase in freight rates will **buy call options.**
  - The charterer is short in freight, and hence the risk is that freight rates may rise.
  - He does not want his freight costs in any of the six months to increase above US$ 50.000/day, and therefore he buys a BPI 4TC Q3+Q4 2008 **call option** with a strike price of US$ 50.000, paying a US$ 4.000/day premium.
  - If the average BPI 4TC rate in the market is below the strike price of US$ 50.000/day in any of the six months, the call option will expire worthless and the charterer will be able take advantage of the lower rates in the market.
  - If the average BPI 4TC rate in the market increases above US$ 50.000/day in any of the six months, the call option will be exercised; in this case, the (maximum) freight cost will be the strike price plus the option premium (US$ 54.000/day).



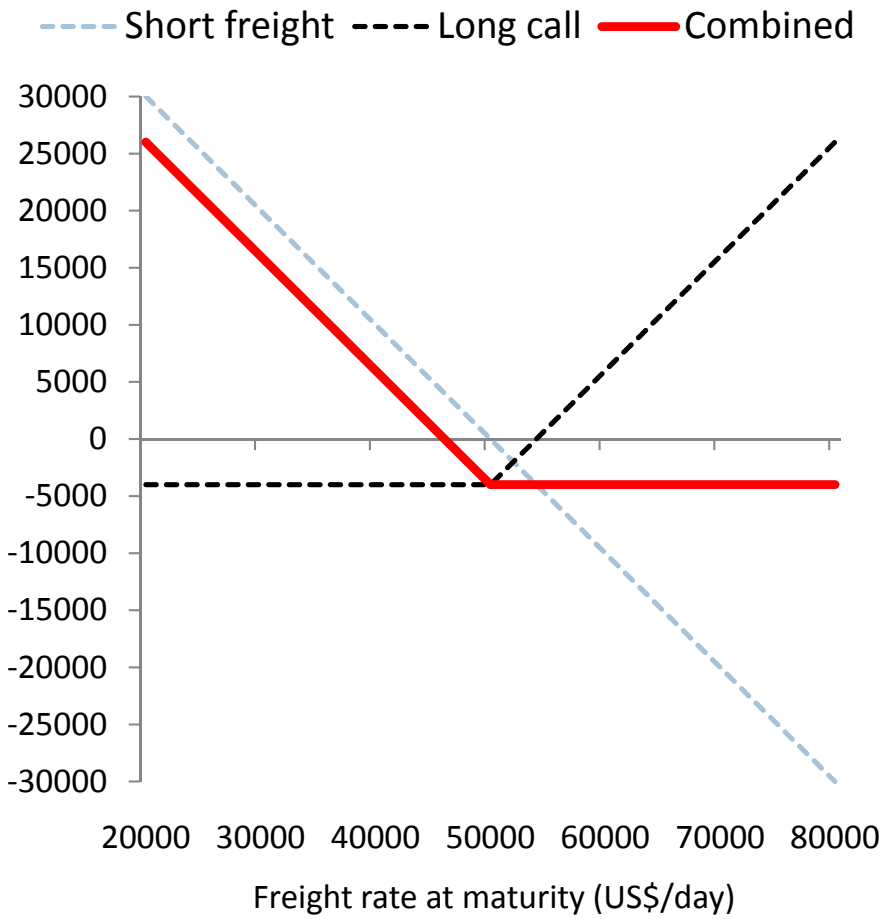
The charterer insures against rising freight rates.

Risk management strategies using freight options (3)

The shipowner‘s hedge



The charterer‘s hedge



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Option trading strategies (1)

- In mid-June 2007, a Panamax shipowner is concerned about the **volatility in the freight market** and wants to secure his freight income for 2008. The Calendar 2008 FFA contract for the BPI 4TC average is quoted at US$ 36.500/day.
- There is a quote from a broker for **Cal-08 BPI 4TC put options** with a strike price of US$ 33.500/day for a premium of US$ 3.000/day.
- The contract is a **strip of 12 options** for each of the 12 months of the year 2008. Each option well be settled separately at the end of each month and the **settlement rate** will be calculated as the **average** of the month for BPI 4TC; the total payoff for each month will be:

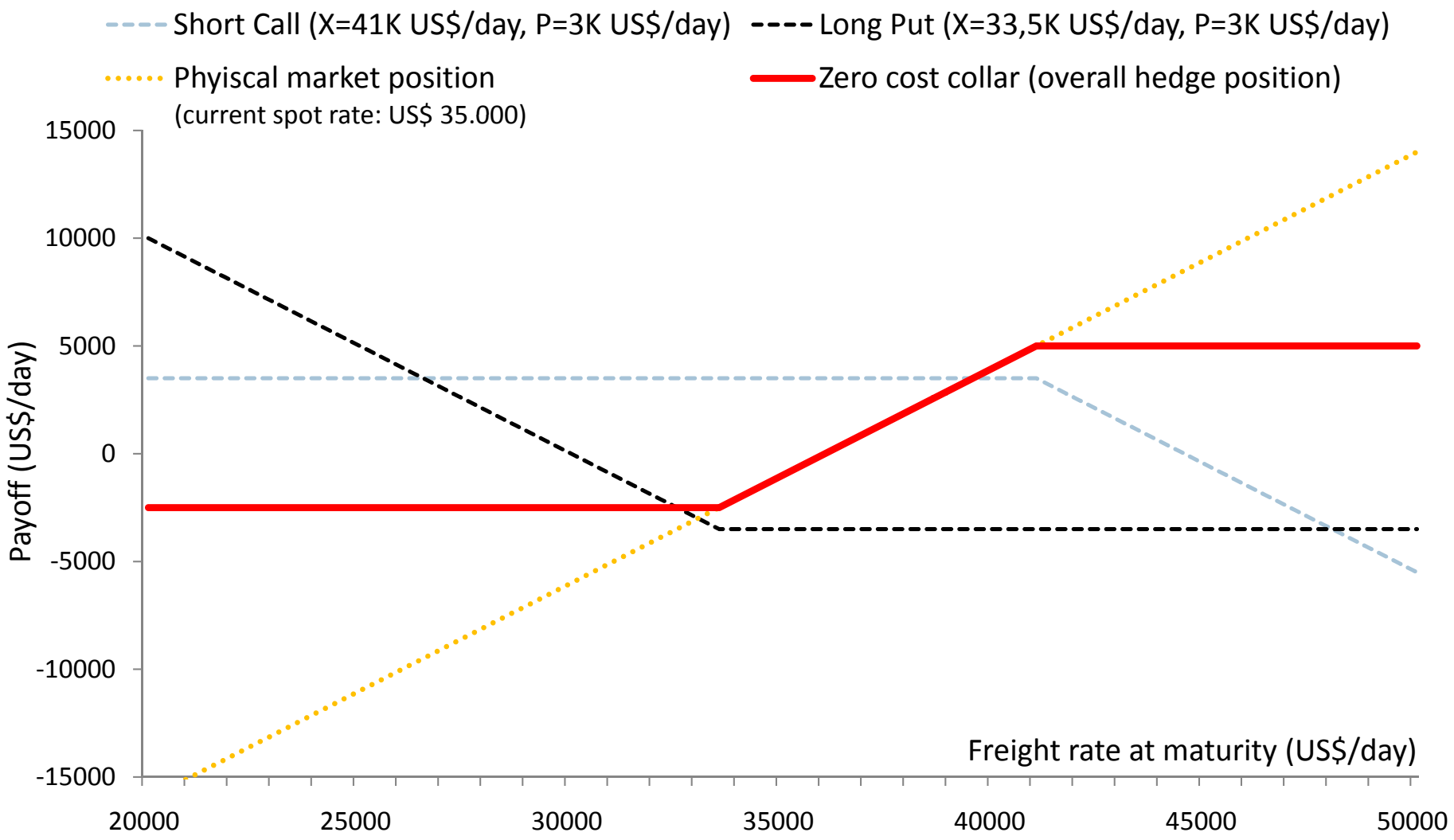
$$\max(33.500 - \varnothing S, 0) \times \text{number of days in the month}$$

- While this hedge guarantees the owner a minimum payoff of US$ 33.500/day, it is an expensive strategy – the owner has to pay an upfront option premium of US$ 1.098.000 (= US$ 3.000/day × 366 day).

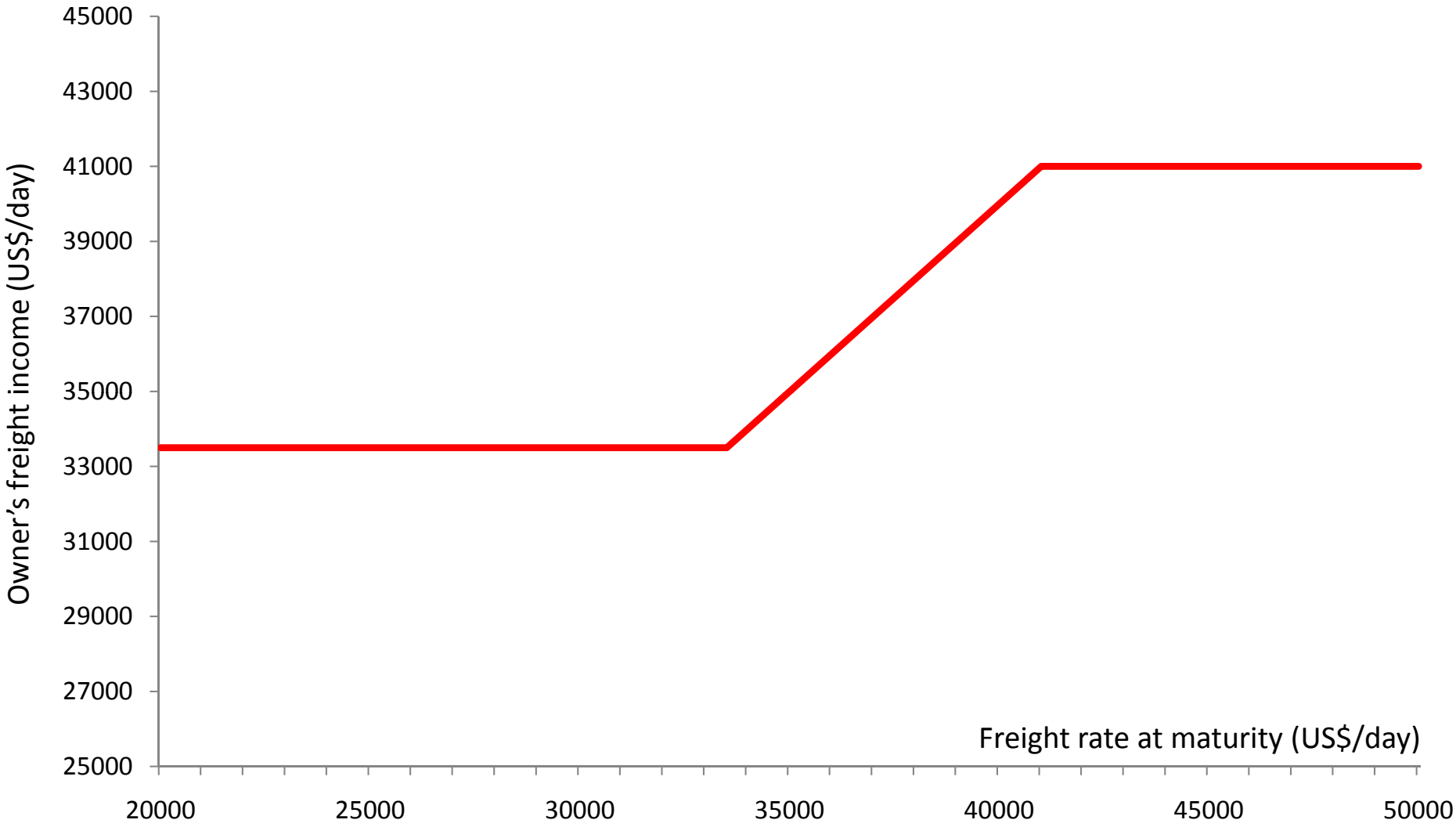
Option trading strategies (2)

- One possibility for the shipowner is to “sacrifice” some of the upside potential by selling an out-of-the money call option at a higher strike price.
- Assume that the broker has identified a counter-party, who agrees to sell to the owner the Cal-08 4TC puts with a US$ 33.500/day strike price, and to buy from the owner the Cal-08 4TC calls with a US$ 41.000/day strike price.
- The premia from the long-put and the short-call positions match exactly, hence the strategy is a zero cost strategy (**zero cost collar strategy**).
- The combined physical and options positions guarantee the owner’s income being between US$ 33.500/day and US$ 41.000/day for every month in 2008.
  - In contrast, if the owner opted for the linear FFA hedge, his income would be locked in at US$ 36.500/day.
  - The collar strategy provides more flexibility and allows the owner to take advantage of potential upside while at the same time being protected on the downside.

Option trading strategies (3)

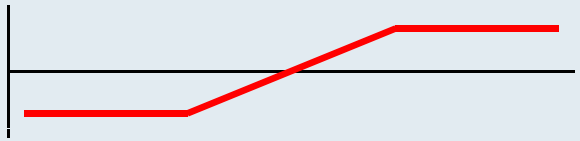
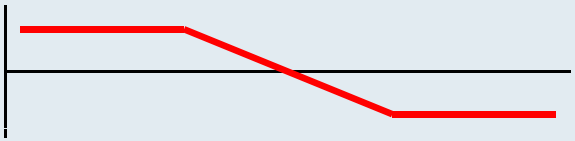
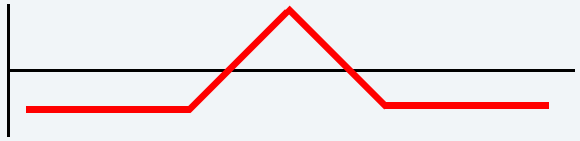
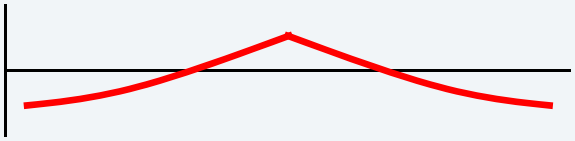
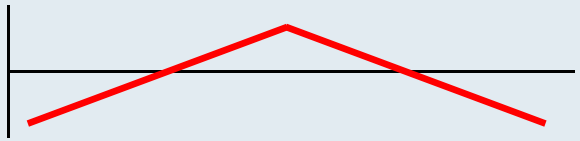
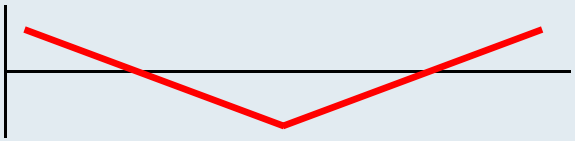
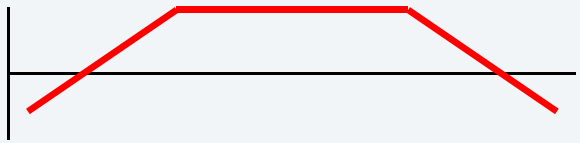
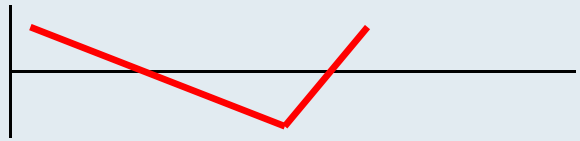


Option trading strategies (3)



Option-trading strategies (5)

- **Spread trading strategies** involve taking a position in two or more options of the same type (i.e., two or more calls, two or more puts or both calls and puts):

Bull spread:		Bear spread:	
Butterfly spread:		Calendar spread:	
Long straddle:		Short straddle:	
Long strangle:		Short strangle:	
Strip:		Strap:	

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Different approaches to pricing freight options

- A **closed-form solution** is the solution to a differential equation that expresses the change in option value relative to all the key variables which affect its value.
  - Closed-form solutions are flexible and very easy to use.
  - The more complicated the underlying process and the more complicated the type of the option to be priced, the more difficult it is to derive a closed-form solution.
- **Monte Carlo (MC) simulation** involves simulating the underlying market variable and calculating the expected option payoff at maturity.
  - Performing a large number of simulations, one can derive an empirical distribution of the option payoffs; the average of these payoffs across a large number of simulations is then discounted back to obtain the present value of the option.
  - MC accommodates path-dependent options, e.g., average price freight options.
- Building the **underlying price tree** is a method to price American options, but it cannot easily accommodate path-dependent options such as freight options.

Challenges in pricing freight options

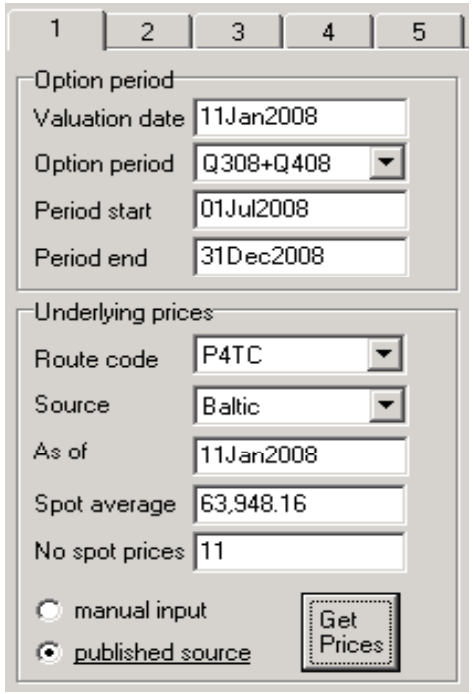
- The underlying asset is the freight rate produced by the Baltic Exchange.
  - It is a **non-tangible asset** because freight rates reflect the cost of providing the service of seaborne transportation which cannot be stored or carried forward in time.
  - There is **no cost-of-carry relationship**, and hence arbitrage between the underlying spot freight market and options across time and space is limited.
  - But: FFAs on most routes are traded contracts, and hence the information contained in the FFA rates should be used when pricing freight options.
- Freight options are settled as “arithmetic average price Asian options”.
  - **Average spot price** over a specified period prior to maturity is used as underlying price for payoff calculation; this ensures that settlement rates are not susceptible to large moves due to high volatility or market manipulation on a specific trading day.
  - There is no closed-form solution for arithmetic average price options; the arithmetic average of a set of lognormal distributions does not have analytically tractable properties, but there are analytical approximations for valuing average price options.

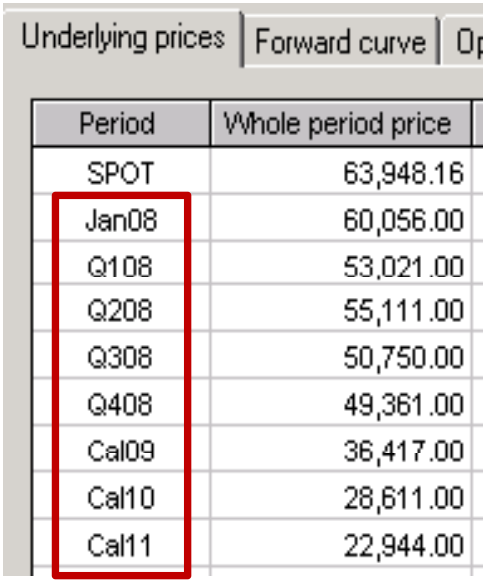
Pricing freight options: A brief model overview

- Plain-vanilla option pricing models (not appropriate for Asian options):
  - **Black-Scholes (1973):** Show that options can be priced by constructing a risk-free hedge through dynamically managing a portfolio of the underlying asset and cash.
  - **Black (1976):** Gives the value of a European option written on a futures or a forward contract ($F_{0,T}$) which matures at some time s in the future (where s>T).
- **Turnbull-Wakeman (1991)** approximation:
  - Based on Black's (1976) model, but it adjusts the mean and variance of the underlying process to be consistent with the exact moments of the arithmetic average.
- **Lévy (1997)** and **Haug et al. (2003)** discrete approximations:
  - Extend the TW-approximation and use a discrete (rather than a continuous) approximation of the formula to value Asian options.
- Additional models: Curran (1992) approximation, Modified Black (1976) model for freight options (Koekebakker et al., 2007),…

Implementing the models using the Softmar tool (1)

- On 11 January 2008, we buy a Q3+Q4 BPI 4TC call option with strike of US$ 65.000/day.
- This contract is a **strip of six options** for each of the six months in the second half of the year 2008.
- Each option will be settled separately at the end of each month. The respective **settlement rate** will be calculated as the **average** of the month for BPI 4TC.



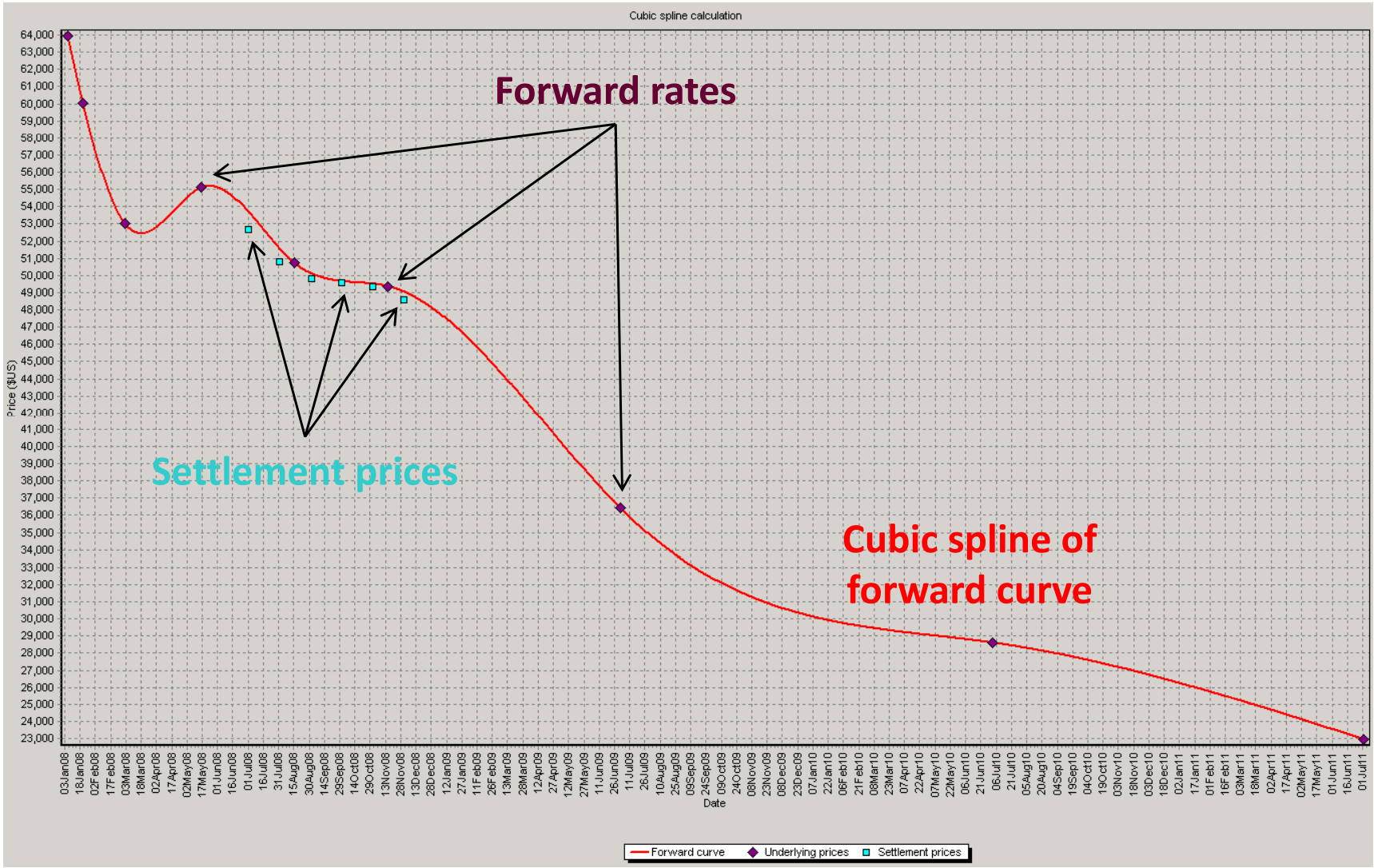


Forward rates

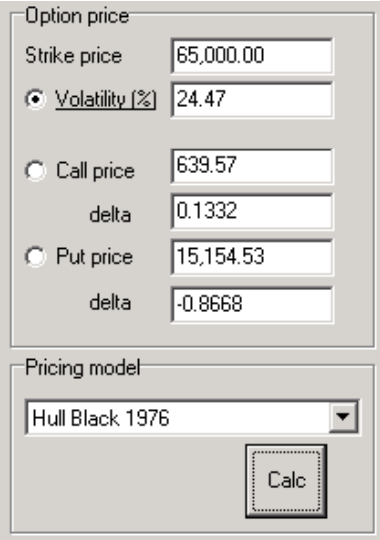
Assumptions:

- Cubic spline of forward curve
- Risk-free interest rate: 3% p.a.
- Volatility: 24.47% p.a.
  (historical volatility based on the last 180 spot rates)

Implementing the models using the Softmar tool (2)



Implementing the models using the Softmar tool (3)



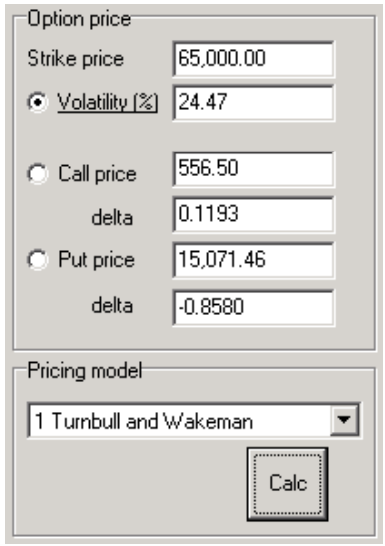
- The **Black (1976) model** delivers a call price of US$ 639,57/day.
- This implies a total call premium of US$ 117,680 (= US$ 639,57/day × 184 days) which must be paid upfront.
- The total premium is the sum of the premiums for the six separate monthly options in the second half of the year 2008.

Underlying prices | Forward curve | Option price | Defaults

Month	Settlement Price	t	t/365	d1	d2	N(d1)	N(d2)	N(-d1)	N(-d2)	Call Price ($/day)	Put Price ($/day)	Days p/month	Call Premium	Put Premium	Call Delta	Put Delta	Gamma
									TOTAL	639.57	15,154.53	184	117,680.67	2,788,433.34	0.1332	-0.8668	0.0000
Jul08	52,700.26	203	0.5562	-1.0582	-1.2407	0.1450	0.1074	0.8550	0.8926	651.20	12,747.42	31	20,187.23	395,170.14	0.1450	-0.8550	0.0000
Aug08	50,779.01	234	0.6411	-1.1622	-1.3581	0.1226	0.0872	0.8774	0.9128	544.97	14,495.06	31	16,894.00	449,346.91	0.1226	-0.8774	0.0000
Sep08	49,841.29	264	0.7233	-1.1719	-1.3800	0.1206	0.0838	0.8794	0.9162	553.17	15,386.49	30	16,595.07	461,594.85	0.1206	-0.8794	0.0000
Oct08	49,584.50	295	0.8082	-1.1206	-1.3406	0.1312	0.0900	0.8688	0.9100	639.45	15,685.67	31	19,822.89	486,255.76	0.1312	-0.8688	0.0000
Nov08	49,336.04	325	0.8904	-1.0787	-1.3096	0.1404	0.0952	0.8596	0.9048	719.59	15,970.66	30	21,587.55	479,119.91	0.1404	-0.8596	0.0000
Dec08	48,579.66	356	0.9753	-1.0841	-1.3257	0.1392	0.0925	0.8608	0.9075	728.84	16,675.67	31	22,593.93	516,945.76	0.1392	-0.8608	0.0000

Source: Softmar

Implementing the models using the Softmar tool (4)



- The **Turnbull-Wakeman (1991)** approximation delivers a call option price of US$ 556,50/day.
- This implies a total call premium of US$ 102,396 (= US$ 556,50/day × 184 days), which must be paid upfront.
- The total premium is the sum of the premiums for the six separate monthly options in the second half of the year 2008.

Underlying prices | Forward curve | Option price | Defaults

Month	Settlement Price	t	t/365	d1	d2	N(d1)	N(d2)	N(-d1)	N(-d2)	Call Price ($/day)	Put Price ($/day)	Days p/month	Call Premium	Put Premium	Call Delta	Put Delta	Gamma
									TOTAL	556.50	15,071.46	184	102,395.84	2,773,148.51	0.1193	-0.8580	0.0000
Jul08	52,700.26									542.55	12,638.78	31	16,819.16	391,802.08	0.1278	-0.8556	
Aug08	50,779.01									458.76	14,408.85	31	14,221.43	446,674.35	0.1080	-0.8730	
Sep08	49,841.29									476.99	15,310.31	30	14,309.58	459,309.36	0.1075	-0.8710	
Oct08	49,584.50									560.84	15,607.06	31	17,385.98	483,818.85	0.1181	-0.8579	
Nov08	49,336.04									644.08	15,895.16	30	19,322.30	476,854.66	0.1277	-0.8459	
Dec08	48,579.66									656.04	16,602.88	31	20,337.39	514,689.21	0.1267	-0.8445	

Source: Softmar

Comparing the models

Model	Call option	Put option
Black-Scholes (1973)	804.61	14,187.10
Black (1976)	638.57	15,154.53
Turnbull-Wakeman (1991)	556.50	15,071.46
Lévy (1997)	555.83	15,070.79
Curran (1992)	555.90	15,070.86

Q3+Q4 BPI 4TC call option; Strike price: US$ 65.000/day; Valuation date: 11 January 2008
Assumptions: Risk-free rate: 3% p.a.; Volatility = 24.47% p.a.

- All three approximations (Turnbull-Wakeman, Lévy, and Curran) deliver very similar call and put option premia.
- The Black (1976) model results in higher option premia because it uses a higher volatility as input into the model (not adjusted for the moments of the arithmetic average).
- The discrepancies between the model prices become smaller with longer maturity.

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Comparison of freight rate option pricing models (1)

- In order to better evaluate the different option pricing models, we compare the model prices with actual prices from the book of a large grain trading company:

  - Mean percentage error:

$$MPE = \frac{1}{N} \sum_{n=1}^{N} \frac{P_n^{Model} - P_n^{Market}}{P_n^{Market}}$$

  - Mean absolute percentage error:

$$MAPE = \frac{1}{N} \sum_{n=1}^{N} \frac{\left| P_n^{Model} - P_n^{Market} \right|}{P_n^{Market}}$$

Data set and assumptions: The sample contains 35 BCI options and 140 BPI options over the period from 2006 to 2009. Freight rate volatility is computed using the freight rates of the subsequent 360 trading days. Treasury bill yields at the respective contract dates are taken as the risk-free interest rate.

Comparison of freight rate option pricing models (2)

	MPE	MAPE	MPE	MAPE
	BCI call options		BPI call options	
Black-Scholes (1973)	14.48	31.86	-22.93	48.84
Black (1976)	7.51	31.26	-36.17	56.00
Turnbull-Wakeman (1991)	-8.18	35.14	-42.93	62.41
Lévy (1997)	-8.35	35.21	-42.87	62.35
Curran (1992)	-8.33	35.19	-42.87	62.35
	BCI put options		BPI put options	
Black-Scholes (1973)	13.15	60.30	-42.02	56.70
Black (1976)	17.23	33.72	-42.75	48.78
Turnbull-Wakeman (1991)	-0.70	41.18	-49.21	54,00
Lévy (1997)	-0,85	41,29	-49,27	54,05
Curran (1992)	-0.96	41,39	-49,28	54,06

Comparison of freight rate option pricing models (3)

Summary of results:

- Using a 360 day rolling window to compute the freight rate volatility, the three approximations work reasonably well **on average** for Capsize contracts (low average MPE), but not for Panamax contracts (where the model **underestimates** the market price).
- In both markets the mean absolute deviation (MAPE) is considerably large, and hence all models' pricing accuracy for the individual contracts is low.

Potential explanations for deviations:

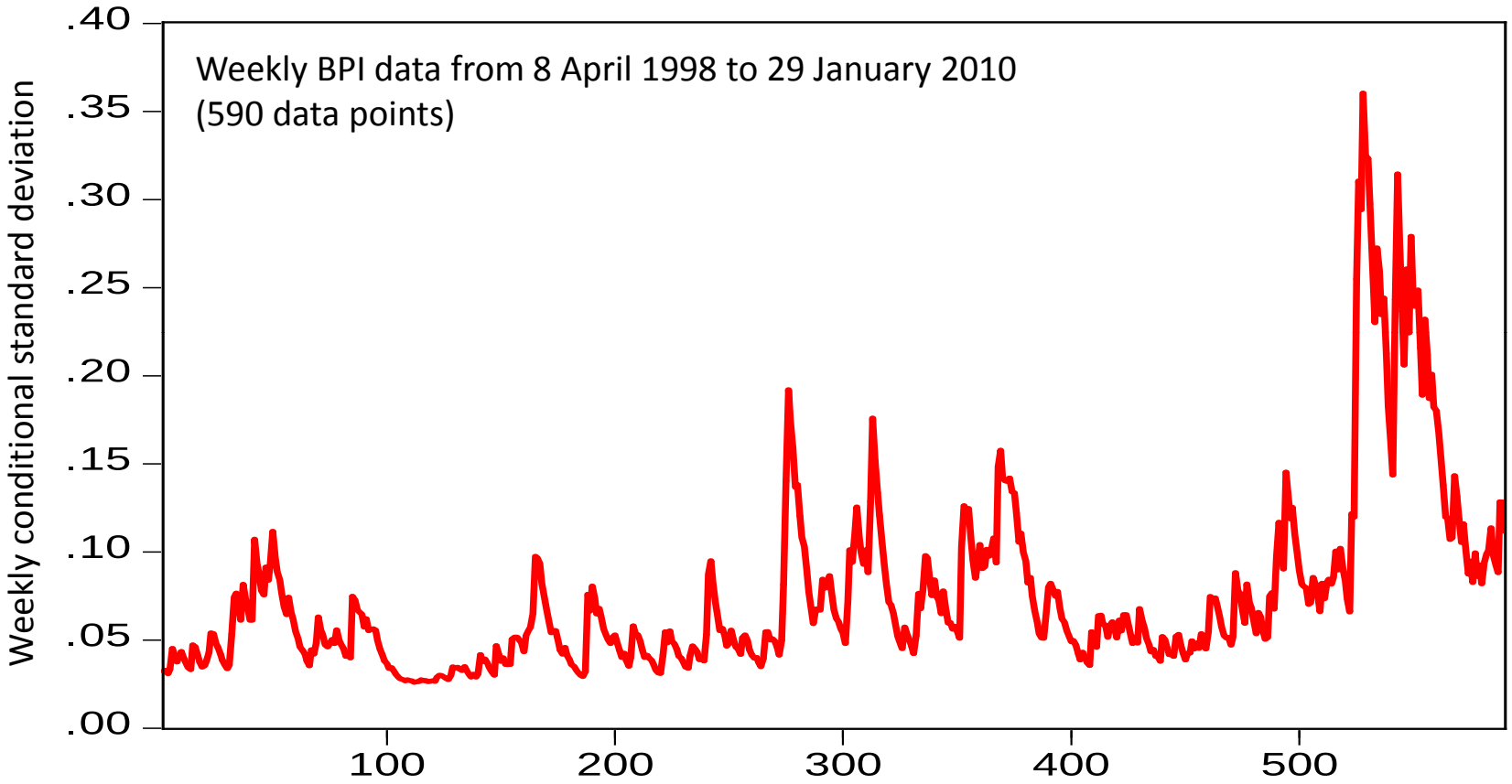
- **Liquidity risk:**
  - Liquidity refers to the ease of trading (transaction costs; demand pressure; asymmetric information; difficulty to locate a counterparty → search cost is particularly relevant in over-the-counter markets in which there is no central marketplace).
  - Liquidity tends to be higher for Capesize contracts compared to Panamax contracts.

Comparison of freight rate option pricing models (4)

- **Counterparty risk:**
  - In an over-the-counter option contract (without clearing), the risk to the option buyer is that the writer will not buy or sell the underlying asset as agreed.
  - Institutional investors (presumably the more sophisticated market participants) tend to trade Capesize contracts rather than Panamax contracts.
- **Volatility effects:**
  - Implied option volatility is higher on average than realized volatility (**market price of volatility risk**).
  - Time-varying volatility: Empirical evidence for **volatility clustering** with high and low volatility states; rolling windows cannot fully capture this effect.
  - **Volatility term structure** (volatility tends to decline with longer time to maturity due to mean reversion) and **volatility smile** (volatilities for ITM and OTM options tend to be higher than those for ATM options).
- **Market inefficiencies**

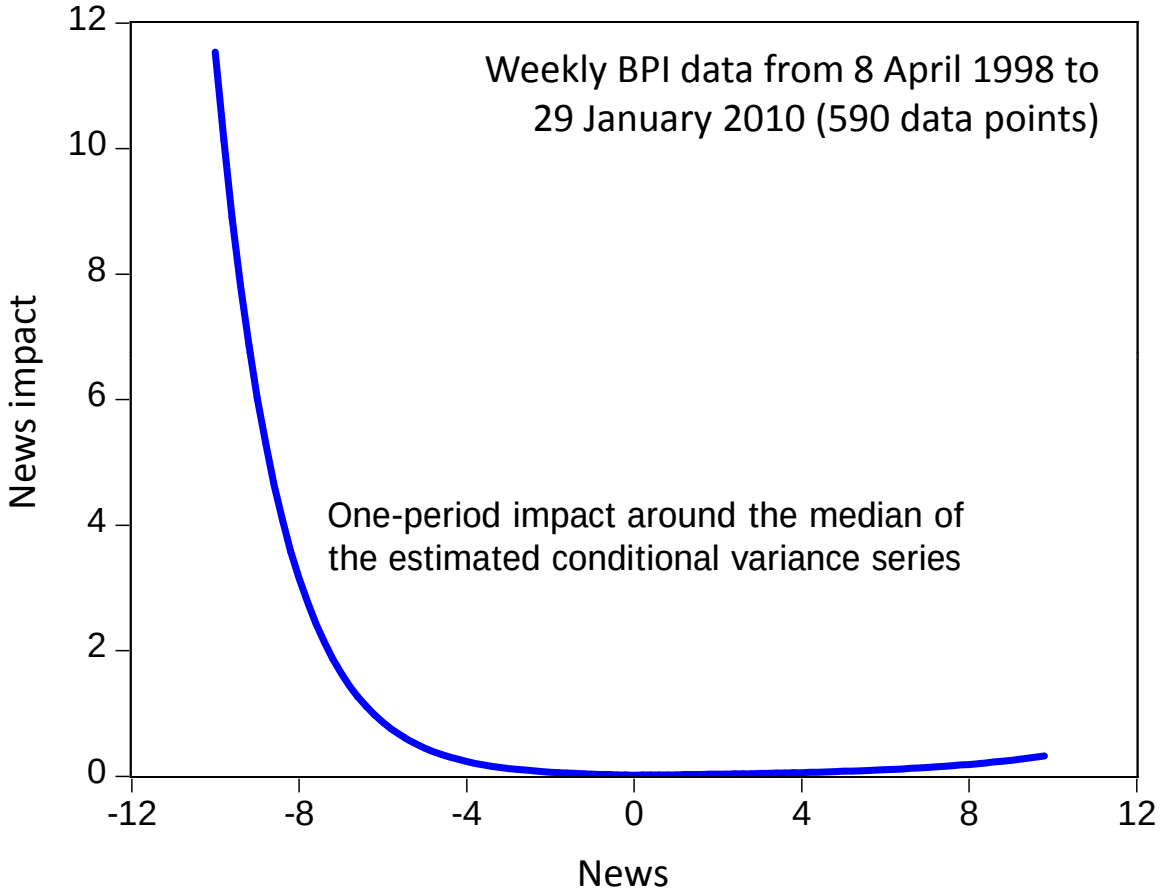
Time-varying volatility of freight rates

Estimated time-varying volatility of BPI rates using a GARCH (1,1) process:



The leverage effect of freight rates

Estimated news impact curve of BPI rates using an EGARCH (1,1) process:



Asymmetric volatility effect:
Downward movements of freight rates are followed by higher volatilities than upward movements of the same magnitude.