Abandonship as a Real Option JAN 2015

 

Sven Sander has just been hired to advise Lars Haug, CEO of North American Tankers (NAT), when to scrap his aging Suezmax tankers. Lars had built NAT from scratch, starting with three newly built tankers in 1997, to now an impressive fleet of 20 tankers. The NAT fleet consists solely of Suezmax double-hull tankers of around 156,000 dwt each, which are always employed in the spot market. **Table 1** shows the distribution of vessel age as of December 2013, plus the end year balance sheet with those tankers at the carrying value specified in column H. Generally Lars acquired tankers from the second hand "market", sometimes as in 2004-2006 when spot rates were high, and more recently 2009-2011 when spot rates were relatively low. Now the average fleet age is around 12.5 years, with a remaining life until 25 of around 12.5 years, so Lars believes that abandonment value is a significant part of the total value of the fleet.

Sven had just completed a real options course at graduate business school, and believes that the abandonment value should be based on real option theory. The primary entry and exit theory based on stochastic prices such as spot tanker rates is documented in Dixit and Pindyck (1994), extending Dixit (1989, 1992) and Tourinho (1979). The solution of the model provides a pair of trigger prices for entry and exit. The difference between the two trigger prices is *hysteresis*, which could be defined as the delay in reactions between investment and abandonment. If the current price of the output is between the two triggers, the firm would be hesitant in making a decision to invest (if idle), or to abandon (when active).

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 Acknowledgements: Parts of this case were originally prepared by Christina Iacovou, and then revised by Dean Paxson. While many figures are similar to that in the Nordic American Tankers Annual Report 2013, the characters are fictitious. This case is not intended as an illustration of either good or bad business practices.

Paxson (2005) considers the possible strategic actions in asset investments, including the opportunity to expand, contract and suspend operations given the volatile nature of future trigger values. These alternatives include remaining idle, building and operating assets, expanding, contracting (slow sailing), suspending (mothballing for ships), reverting to normal service or reduced service capacity, or abandoning.

Recently Adkins and Paxson (2014) have developed a simple model of abandonment, assuming that the opportunity of abandonment arises post-investment, when there is no opportunity for a re-investment, and the salvage value is stochastic.

1 The Dixit and Pindyck (1994) Model:

1.1 General Assumptions:

In Dixit and Pindyck (1994), the price of the output is assumed to be the only stochastic factor for the investment and the abandonment decisions, and it follows a geometric Brownian motion:

$$dP = (\delta)Pdt + \sigma Pdz \qquad (1)$$

where P is the price of output, δ_P the asset yield in this case, σ is the instantaneous volatility rate and dz is the standardized Wiener process. The variable costs of the operations (C) are assumed to be known and constant, and the risk free interest rate is exogenously fixed at r. The options to alter states/operations are assumed to be perpetual.

The firm must incur a lump sum cost K to invest in the project, and a lump sum cost X to abandon it. The sunken investment costs and the abandonment benefits, ignoring taxes and subsidies, are assumed to be constant in perpetuity. A negative value for X indicates the amount that would be gained when the ship owner sells an old ship for demolition.

1.2 The Model:

An idle firm will find it optimal to remain idle as long as P remains below P_H (the trigger price of entry), and will invest as soon as P reaches the threshold P_H . An active firm will remain active if P remains above P_L(the trigger price of exit), but will abandon its operations otherwise. The value of the firm is a function of the exogenous state variable P. The value of the option to invest is denoted as $V_0(P)$, whereas $V_1(P)$ is the value of the active firm. Over the range $(0, P_H)$, an idle firm will maintain its option to invest, whereas over the range (P_L, ∞) an active firm will remain active, holding its option to abandon until the price falls below P_L.

In a stochastic model allowing for both investment and abandonment, there are two differential equations that the valuation functions must satisfy (Paxson, 2015):

$$\frac{1}{2}\sigma^2 P^2 V_0''(P) + (r-\delta)PV_0'(P) - rV_0(P) = 0 \quad (2)$$

$$\frac{1}{2}\sigma^2 P^2 V_1''(P) + (r-\delta)PV_1'(P) - rV_1(P) + P - C = 0 \quad (3)$$

Equation 2 represents the differential equation of an idle firm, whereas Equation 3 represents the differential equation of an active firm. The general solutions of the two equations are:

$$V_0(P) = A_1 P^{\beta_1} \quad (4)$$

$$V_1(P) = B_1 P^{\beta_1} + B_2 P^{\beta_2} + \frac{P}{\delta} - \frac{C}{r} \quad (5)$$

where A_1, $B_1$and B_2 are coefficients to be determined, and β_1 and β_2 are the roots of the following quadratic equations:

$$\beta_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} > 1 \quad (6)$$

$$\beta_2 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} - \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} < 0 \quad (7)$$

The first two terms of Equation 5 represent the value of the option to abandon, whereas the last two terms represent the value of the on-going project. The likelihood of abandonment in the not too distant future becomes extremely small as P goes to infinity, so the value of the abandonment option should go to zero as P becomes very large. Hence, the coefficient B_1 should be zero, and therefore, Equation 5 can be written as:

$$ROV_1 = V_1(P) = B_2 P^{\beta_2} + \frac{P}{\delta} - \frac{C}{r} \quad (8)$$

Equation 8 is valid when P is within the range of (P_L, ∞). The first term represents the value of the option to abandon, whereas the second term represents the perpetual net value of operating the asset (Paxson, 2015). At P_H, the firm pays the lump sum cost K to exercise its investment option, giving up this asset of value $V_0(P_H)$ to get the live project which has a value $V_1(P_H)$. Therefore, the value matching and smooth pasting conditions are:

$$V_0(P_H) = V_1(P_H) - K \quad (9) \qquad V_0'(P_H) = V_1'(P_H) \qquad (10)$$

Similarly, at the abandonment threshold P_L, the value matching and smooth-pasting conditions are:

$$V_1(P_L) = V_0(P_L) - X \quad (11) \qquad V_1'(P_L) = V_0'(P_L) \qquad (12).$$

Given Equations 4 and 8 for $V_0(P)$ and $V_1(P)$, the above conditions can be written as:

$$-A_1 P_H^{\beta_1} + B_2 P_H^{\beta_2} + \frac{P_H}{\delta} - \frac{C}{r} = K \qquad (13)$$

$$-\beta_1 A_1 P_H^{\beta_1 - 1} + \beta_2 B_2 P_H^{\beta_2 - 1} + \frac{1}{\delta} = 0 \qquad (14)$$

$$-A_1 P_L^{\beta_1} + B_2 P_L^{\beta_2} + \frac{P_L}{\delta} - \frac{C}{r} = -X \qquad (15)$$

$$-\beta_1 A_1 P_L^{\beta_1 - 1} + \beta_2 B_2 P_L^{\beta_2 - 1} + \frac{1}{\delta} = 0 \qquad (16)$$

These four equations determine the four unknowns –the thresholds P_H, P_L and the coefficients A_1 and B_2. The thresholds should satisfy the condition $0 < P_L < P_H < \infty$, and the coefficients A_1 and B_2 should be positive.

The traditional Marshallian approach also provides two trigger points. Investment is justified when the price of the output is greater than or equal to the sum of the operating cost and the interest on the sunk cost of investment (C+rK), whereas abandonment is justified when the price of the output falls to a level below or equal to the operating cost minus the interest on abandonment cost (C-rX).

2 The Adkins and Paxson (2014) Model:

2.1 General Assumptions:

The firm is assumed to be in a monopoly position, and has an opportunity to abandon after the investment has been realized (by obtaining the scrap value), but then there is no option to reinvest at K. This is appropriate for a bankrupt firm, or where X is far below K and investment funding is problematical.

2.2 The Model:

Adkins and Paxson (2014) treat the prior investment expenditure as a sunk cost, so it is not a factor regarding the abandonment option value. Instead, the abandonment choice is decided by the prevailing levels of the remaining present value for the ship and the value obtained through abandonment. The function depends on the value of V (where P and C are not separately considered) and the abandonment value X. The volatility of demolition is σ_X, the risk neutral drift of X is θ_X, (r-drift, in this case) and ρ_{VX} is the correlation of V and X.

The abandonment option can be defined as:

$$ROV_2 = F(V, X) = AV^{\beta_2}X^{\beta_1} \quad (17)$$

Abandonment is justified whenever the prevailing value for V is sufficiently low while that of X is sufficiently high, since the firm would have to be convinced of the expected benefits accruing from sacrificing an operating project. The value of the option increases as the value of V continues to decline or the value of X continues to rise. Therefore, F is a monotonic increasing function of V and a decreasing function of X, which suggests that $\beta_2 < 0$ and $\beta_1 > 0$.

Owing to value conservation, abandonment is economically warranted when the composite asset values just prior and after exercise are in balance. Just before exercise, the asset value is the sum of the operating present value V and the value of the option to abandon As soon as the option is exercised, the operating value is sacrificed in order to obtain the benefits of abandonment. Consider two threshold points, which signal optimal exercise, $\hat{V}$, for the project present value, and $\hat{X}$, for the abandonment value. Therefore, the value of the asset at the instance of exercise is equal to $\hat{V} + F\left(\hat{V}, \hat{X}\right)$, and the value of the asset just after exercise is denoted by $\hat{X}$. As a result, the value matching relationship is:

$$\hat{V} + A\ \hat{V}^{\beta_2}\hat{X}^{\beta_1} = \hat{X} \quad (18)$$

The smooth pasting conditions have to be fulfilled in order for an optimal exercise to take place. There are two smooth pasting conditions, one for each factor, V and X, respectively, which are expressed as:

$$\hat{V} + \beta_2 A\ \hat{V}^{\beta_2}\hat{X}^{\beta_1} = 0 \quad (19)$$

$$\beta_1 A\ \hat{V}^{\beta_2}\hat{X}^{\beta_1} = \hat{X} \quad (20)$$

The sum of β_2 and $\beta_1 = 1$. The value of the parameter β_2 is the negative root solution of Equation 21:

$$Q(\beta_2,\beta_1)=\tfrac{1}{2}\sigma_V^2\beta_2(\beta_2-1)+\tfrac{1}{2}\sigma_X^2\beta_1(\beta_1-1)$$
$$+\rho_{VX}\sigma_V\sigma_X\beta_2\beta_1+\theta_V\beta_2+\theta_X\beta_1-r=0. \quad (21)$$

Moreover:

$$\hat{V} = \frac{-\beta_2\hat{X}}{1-\beta_2}, \quad (22)$$

$$A = \frac{1}{-\beta_2}\left(-\frac{\beta_2}{1-\beta_2}\right)^{1-\beta_2} \quad (23)$$

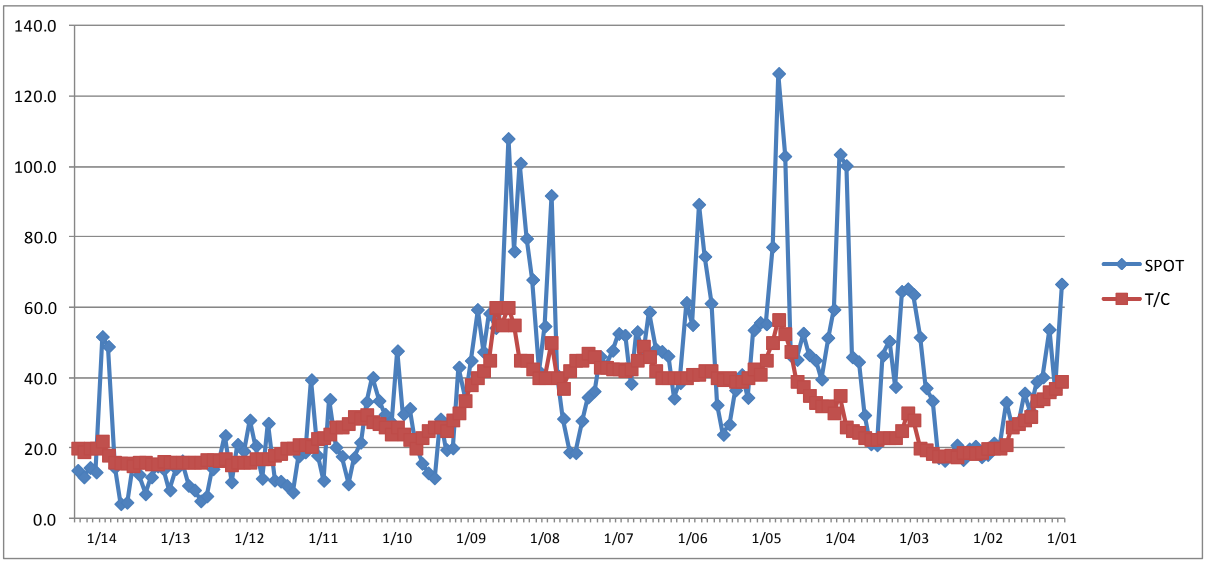
There are four equations, and if it is assumed that $\hat{X} = X$, then there are four unknowns.

3 Shipping Market Information[1]

3.1 The Freight Market:

The freight market is affected by changes in demand and supply, through the competition among owners and charterers. Changes in supply, mainly occurring as a result of the changes in the shipbuilding and scrapping market, are likely to have a gradual effect on demand due to the time lag between order and delivery. Unexpected changes in supply may have a significant impact on the freight market. For instance, changes in regulations regarding old ships, bad weather conditions or unexpected political issues, force the supply of the shipping market to decrease, which in turn creates an increase in the freight rates.

Figure 1



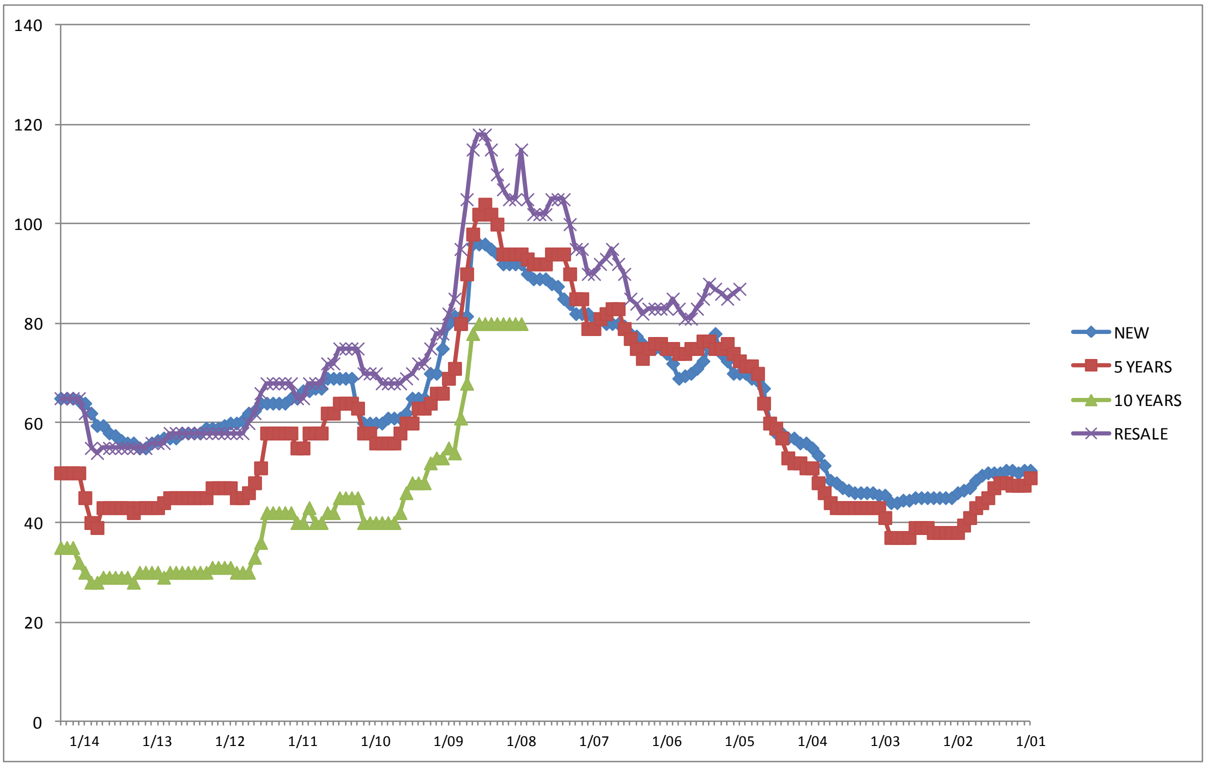
[1] Collected by Christina Iacovou, MSc_QFRM, from R S Platou and Marex Spectron.

Figure 1 represents the monthly spot and one year time charter freight rates for Suezmax tankers for the past fourteen years. The volatile nature of the spot freight rate market is clearly indicated.

3.2 <u>New Building and Second Hand Ship Market</u>:

Figure 2 illustrates the movement of (new building, 5 year and 10 year) ship prices for the last fourteen years. The second-hand vessel market is an auxiliary market. The buying and selling of used ships is unlikely to alter the existing number of ships and the carrying capability in the tanker shipping market. Lars believes that these second hand ship prices are not reflective of frequent transactions, since according to Clarkson Ltd 68 Suezmax tankers were sold and bought during 2009-2013 (perhaps 8 of these were by NAT).

Figure 2

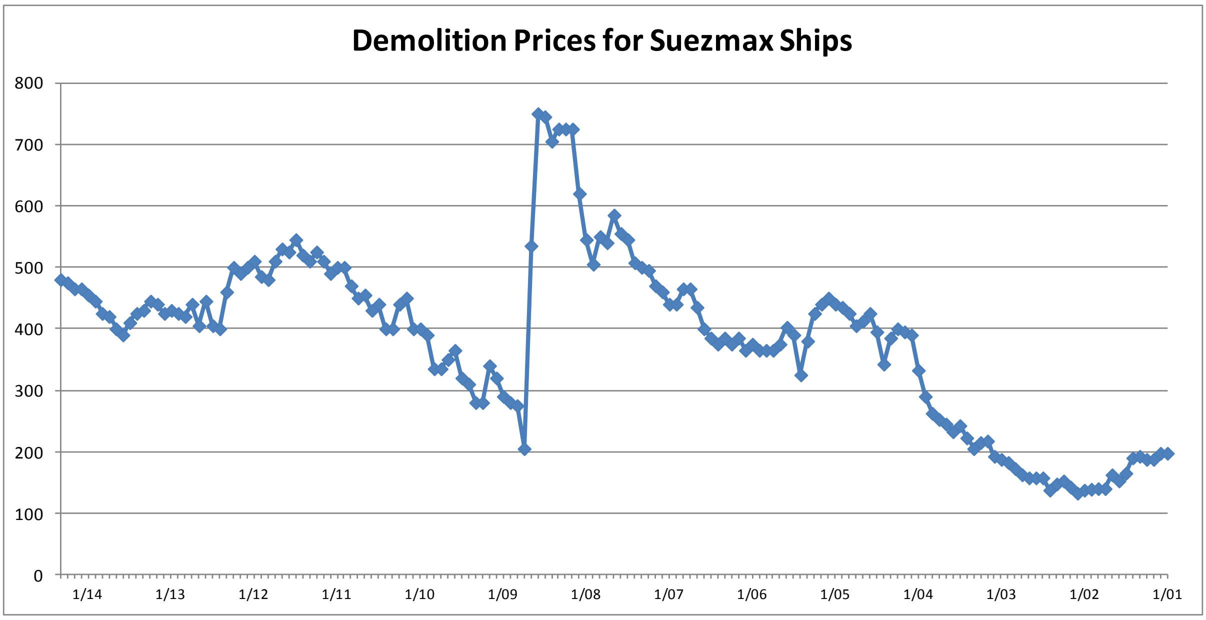


In general, the balance sheet "carrying costs" of ships reflects the historical cost (new building or second hand market purchase) less cumulative depreciation of each vessel. NAT has a particular methodology for determining vessel value impairment. Future cash flows are estimated for each vessel based on the daily time charter equivalent for the remaining operating days utilizing a fifteen year historical average spot market rate for similar vessels, and a salvage value of $9,700,000. A vessel is deemed impaired if the future undiscounted net cash flows are less than the current balance sheet carrying value, which is then reduced to the future discounted net cash flows (discount rate not disclosed). Nevertheless, Lars reports also the aggregate "market value" of the fleet, based on certain estimates by shipbrokers, which is shown in Table 1, cell H30.

3.3 The Demolition/Scrapping Market:

The demolition market is concerned with old vessels that are being scrapped, primarily for the steel value. **Figure 3** illustrates the demolition prices for tankers. The abandonment cost can be calculated by the prices of the demolition market. For instance, May 2014 the price was equal to $480 per lightship (Ldt). According to the IMO a 150000-dwt Suezmax tanker has an overall lightship of 22000. Since NAT's fleet is comprised of 156000-dwt Suezmax tankers, each tanker has a lightship equal to 22880. By multiplying the price per Ldt with the lightship per ship, the abandonment value is estimated to be $480x22880= $10,982,400, or slightly more than assumed by Lars end 2013.

Figure 3



3.4 NAT:

Table 1 shows the average current net revenue per ship and operating costs based on the six months ending June 2014. The Dec 2013 balance sheet is shown in column H, cells H25:H32, with a disclosed "fair value" of $475 million substituted for the fleet carrying value of $911 million, plus current and other assets less real liabilities, for a net asset value per share of $5.49. Column E shows the June 2014 balance sheet with a calculated aggregate annuity value of $674 million substituted for the carrying value. The annuity value is the current apparent average revenue less costs through the remaining life for each ship plus the salvage value discounted at 5%. Column I shows theoretical abandonment values (for some ships using a hypothetical abandonment value using the Adkins and Paxson model). Column K shows the 5% present value of the disclosed salvage value at the end of the 25 years physical life for each ship. These valuations are merely illustrative, and based on assumptions that both Sven and Lars may consider unrealistic (especially based on averages for each ship rather than actuals).

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Table 1

	A	B	C	D	E	F	G	H	I	J	K
1					NAT SUEZMAX DETAILS						
2				2014	2014	2018	2018	Dec-13	2014	2018	2014
3		Built	Vessel Age	Years Left			Years Left	Carrying Value $m	ABANDON ROV		ABANDON PV
4	Nordic Harrier	1997	17	8	$26,049,343	$18,669,836	4	27.8	$2,590,393		$6,565,342
5	Nordic Hawk	1997	17	8	$26,049,343	$18,669,836	4	31.1	$2,590,393		$6,565,342
6	Nordic Hunter	1997	17	8	$26,049,343	$18,669,836	4	29.0	$2,590,393		$6,565,342
7	Nordic Voyager	1997	17	8	$26,049,343	$18,669,836	4	25.0	$2,590,393		$6,565,342
8	Nordic Freedom	2005	9	16	$37,115,222	$32,120,481	12	55.1			$4,443,682
9	Nordic Fighter	1998	16	9	$27,679,946	$20,651,844	5	40.3			$6,252,706
10	Nordic Discovery	1998	16	9	$27,679,946	$20,651,844	5	43.4			$6,252,706
11	Nordic Saturn	1998	16	9	$27,679,946	$20,651,844	5	42.0			$6,252,706
12	Nordic Jupiter	1998	16	9	$27,679,946	$20,651,844	5	43.8			$6,252,706
13	Nordic Apollo	2003	11	14	$34,739,602	$29,232,901	10	58.5			$4,899,159
14	Nordic Moon	2002	12	13	$33,461,982	$27,679,946	9	57.4			$5,144,117
15	Nordic Cosmos	2003	11	14	$34,739,602	$29,232,901	10	59.1			$4,899,159
16	Nordic Sprite	1999	15	10	$29,232,901	$22,539,471	6	41.8			$5,954,959
17	Nordic Grace	2002	12	13	$33,461,982	$27,679,946	9	45.7			$5,144,117
18	Nordic Mistral	2002	12	13	$33,461,982	$27,679,946	9	41.8			$5,144,117
19	Nordic Passat	2002	12	13	$33,461,982	$27,679,946	9	43.4			$5,144,117
20	Nordic Vega	2010	4	21	$42,132,388	$38,218,878	17	80.2			$3,481,741
21	Nordic Breeze	2011	3	22	$42,997,131	$39,269,979	18	61.5			$3,315,944
22	Nordic Aurora	1999	15	10	$29,232,901	$22,539,471	6	22.5			$5,954,959
23	Nordic Zenith	2011	3	22	$42,997,131	$39,269,979	18	62.0			$3,315,944
24	MEAN		12.55	12.45	$32,732,263	$26,792,967	8.45		ADD ROV	ADD ROV	
25	Interest rate	**0.05**		PV	$674,684,224	$547,223,532		$911,400,000	$10,361,572	$0	$108,114,207
26	Scrap Value	$9,700,000		Current Assets	$227,291,000	$227,291,000		$131,396,000			
27	Total Revenue	$243,657,000		Other Assets	$80,600,000	$80,600,000		$74,600,000			
28	Annual Revenues/ Ship	$12,182,850		Liabilities	269733000	269733000		$269,263,000			
29	Operating Costs	$12,891,700		Net Value	$712,842,224	$585,381,532		$411,733,000	$723,203,796		
30	Days Operating	344					"Market Value"	$475,000,000			
31	Revenue-Cost/ Ship 2014	**$3,014,600**		Shares	89000000	89000000		75000000	89000000		
32	Six Months June 2014		PerShip pa	NAV	$8.01	$6.58		**$5.49**	$8.13		
33	Gross Revenue	$160,812,000									
34	Voyage Expense	$93,175,000		E4=	$B$31/$B$25*(1-1/(1+$B$25)^D4)+(9700000/(1+$B$25)^D4)				K4=	$B$26/(1+$B$25)^D4	
35	Net Revenue	$67,637,000	$6,763,700								
36	Operating Costs	$37,491,000	$3,749,100								
37	Net Operating	$30,146,000					Asset Yield	8.94%			
38	Drydock days	21									

Table 2

	A	B	C	D
1		**DIXIT & PINDYCK 1994**		
2	V	Value	25.6997	
3	P	Net Revenue	6.7637	Revenue Per Ship From Annual Report
4	K	Investment Cost	25.0000	Estimated second hand price
5	C	Variable Operating Cost	3.7491	Operating cost estimation
6	X	Abandonment Cost	-9.7000	Scrap Value (Annual Report)
7	r	Risk Free Rate	0.0750	Model AP'!$B$8
8	δ	Asset Yield	0.0894	Model AP'!$B$9
9	σ	Volatility	0.5000	Template
11	β1=		1.5118	
12	β2=		-0.3969	
14	Vo(P)		33.8492	
15	V1(P)		52.1490	
16	NPV		0.6997	
17	A1		1.8814	
18	B2		56.4805	
19	**PH**		12.9918	
20	**PL**		2.3531	
21	**PH-PL**		10.6387	
22	Eq.13		0.0000	
23	Eq.14		0.0000	
24	Eq.15		0.0000	
25	Eq.16		0.0000	
26	SUM		0.0000	
27	SOLVER	Set C26=0, Changing C17:C20		
28	V_{PL}		-23.6559	
29	$\mathbf{W_K}$		5.6241	
30	$\mathbf{W_A}$		4.4766	
31	$\mathbf{W_K\text{-}W_A}$		1.1475	
32	V_{WA}		0.1064	
33	AOV	Value of Option to Abandon	26.4493	
34	V	Value of Operating Ship	25.6997	
35	β1=	0.5-((C7-C8)/(C9^2))+SQRT(((((C7-C8)/(C9^2))-0.5)^2)+(2*(C7/(C9^2))))		
36	β2=	0.5-((C7-C8)/(C9^2))-SQRT(((((C7-C8)/(C9^2))-0.5)^2)+(2*(C7/(C9^2))))		
37	V_{PL}	C20/C8-C5/C7		
38	Vo(P)	C17*(C3^C11)		
39	V1(P)	C18*(C3^C12)+(C3/C8)-(C5/C7)		
40	NPV	(C3/C8)-(C5/C7)-C4		
41	Eq.13	(C17*(C19^C11))-(C18*(C19^C12))-(C19/C8)+(C5/C7)+C4		
42	Eq.14	(C11*C17*(C19^(C11-1)))-(C12*C18*(C19^(C12-1)))-(1/C8)		
43	Eq.15	(-C17*(C20^C11))+(C18*(C20^C12))+(C20/C8)-(C5/C7)+C6		
44	Eq.16	(-C11*C17*(C20^(C11-1)))+(C12*C18*(C20^(C12-1)))+(1/C8)		
45	$\mathbf{W_K}$	C5+C7*C4		
46	$\mathbf{W_A}$	IF((C5-C7*C6)>0,C5-C7*C6,0)		
47	V_{WA}	C30/C8-C5/C7		
48	AOV	C18*(C3^C12)		
49	V	(C3/C8)-(C5/C7)		

Table 3

	A	B	C
1			**Adkins & Paxson Oct 2014**
2	INPUT		
3	V	25.6997	PV OF SHIP
4	X	9.7000	From NAT financial statements
5	σV	0.5000	Template
6	σX	0.3655	Volatility of demolition prices
7	ρ VX	-0.0430	Correlation freight & demolition prices
8	r	0.0750	
9	θV	0.0894	NPV '!$H$37
10	θX	0.0000	Template
11	OUTPUT		
12	$Q(\beta_1,\beta_2)$	0.0000	0.5*(B5^2)*B19*(B19-1)+0.5*(B6^2)*B18*(B18-1)+B7*B5*B6+B9*B19+B10*B18-B8
13	SP1	0.0000	B20+B19*B17*(B20^B19)*(B21^B18)
14	SP2	0.0000	B18*B17*(B20^B19)*(B21^B18)-B21
15	VM	0.0000	B17*(B20^B19)*(B21^B18)+B20-B21
16	SOLVER	0.0000	Set B16=0, Changing B17:B20
17	A	0.4110	
18	β_1	1.4424	
19	β_2	-0.4424	
20	V*	**2.9753**	
21	X*	9.7000	
22	ROV	**2.5904**	IF(B3>B20,B17*(B3^B19)*(B4^B18),B21-B20)
23	V*/X*	0.3067	

CASE QUESTIONS:

1. **What is the historical volatility of spot tanker freight rates, time charter rates, 5 year and 10 year second hand ship prices, and demolition rates? Are these rates becoming more or less volatile over time?**
2. **Using appropriate parameter values, what is the abandonment price and abandonment value using the Dixit and Pindyck model?**
3. **Using the same appropriate parameter values but stochastic X, what is the abandonment threshold and abandonment value using the Adkins and Paxson model?**
4. **Lars wants Sven to use the Dixit & Pindyck real abandonment option values for the additional ROV to supplement the calculated PV annuities and PV salvage value in Table 1. Why do the real abandonment option values differ using these two models? Which should Sven honestly advocate?**