MARIT. POL. MGMT., JUNE 2009,
VOL. 36, NO. 3, 215–233

Routledge
Taylor & Francis Group

Exploring the link between oil prices and tanker rates

ANGELA POULAKIDAS*† and FRED JOUTZ‡

†Department of Business, Queensborough Community College,
City University of New York, 222-05 56th Avenue, Bayside, NY, USA
‡Department of Economics, Research Program on Forecasting,
The George Washington University, USA

Given the secular and sharp rise in oil prices over the past decade, this study analyses the impact that the spike in oil prices has on tanker rates. We investigate a dynamic model explaining spot tanker rates. The magnitude of the impact of oil prices on the shipping industry, in terms of the level and volatility of spot (voyage) under bull and bear market conditions. The West African–US Gulf Tanker Rates, West Texas Intermediate spot and 3-month futures contract, and US Weekly Petroleum Inventories are analysed using cointegration and Granger causality analysis, from 1997 through 2007, in order to examine the lead–lag relationship between oil prices and tanker freight rates. Our findings show a relationship between spot and future crude oil prices, crude oil inventories and tanker rates. The significant increase of freight rates, and the simultaneous increase in oil prices, during the recent years, provides an intriguing economic environment to identify relationships between shipping market rates and oil prices. These relationships have significant implications for the markets. At the practical level, the better understanding of the relationship between freight rates and crude oil prices can improve operational management and budget planning decisions.

1. Introduction

Oil is the paramount energy source in the global economy and its pricing has profound macroeconomic, political and social effects. An important element of the world oil market is the tanker industry, which moves oil from producer areas to consumer markets. Spot tanker prices are strongly influenced by the crude oil market, specifically spot prices, future contract prices, and petroleum inventories.

Crude oil is commodity traded on global markets. It is subject to relative demand shifts from economic growth globally and by regions. Supply disruptions and shocks in oil exporting countries lead to price volatility. The pricing of crude and petroleum products reflects changing supply and demand including the impact of special entities such as OPEC and even Russia. The final end use price depends on production costs, refining, marketing, and transportation costs of crude oil and petroleum products from producing countries to consumer markets.

In the US, about one-fourth of all energy consumption is for transportation. This is almost entirely supplied by petroleum products. In fact, three-quarters of petroleum consumption is related to transportation and is expected to increase over

*To whom correspondence should be addressed. e-mail: apoulakidas@qcc.cuny.edu

Maritime Policy & Management ISSN 0308–8839 print/ISSN 1464–5254 online © 2009 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/03088830902861094

the next 25 years [1]. Motor gasoline is about 50%, diesel or distillate fuel about 15%, and jet fuel about 10%.

Our study focuses on the relationship between spot tanker rates, crude oil prices and inventories in the US for shipping from West Africa to the US Gulf between 1998 and 2005. We use the Baltic dirty tanker index for very large crude carriers (260 000mt), the spot West Texas Intermediate Crude Oil Price, the NYMEX future contract 3, and crude oil stocks in the analysis. The frequency of observations is the closing price for each week on the Baltic index.

West Africa contributed about 14% of the US total petroleum products imported in 2004. This was about 1.6 million barrels per day and 8% of total consumption. Over 95% came from three countries: Nigeria, Angola and Gabon. West Africa is expected to become an even more important source of imports in the future increasing deep water off-shore oil production in the region. Also, rising demand for oil by southern and eastern Asia is likely to come from the Middle East.

Our results suggest that the spot tanker market is related to the intertemporal relationship between current and future crude oil prices, such that relatively higher expected prices put upward pressure on spot tanker rates. In addition, higher inventories and movements in inventories put downward pressure on spot tanker rates.

This paper is structured into five further sections. We begin with a brief description of the literature on the tanker market and its relationship with the oil market in Section 2. Next, the data series used in the analysis is presented. The fourth Section describes the economic model and econometric methodology. In the fifth section, we present the empirical results from the analysis. This is followed by a discussion of the results and the conclusion.

2. A review of the relationship between the tanker and oil markets

There is a long history of research examining the determinants of tanker prices and their relationship oil prices [2–11]. Kavussanos and Alizadeh-M [12] and Kumar [13] provide a good discussion of the tanker market supply and demand determinants.

The quest for understanding tanker price movements has become more significant because, of the substantial rise in oil tanker prices. Poten & Partners (2004a), a leading ship broker in New York, have noted that VLCC rates are at the highest they have been in over 10 years. Tanker rates, which averaged less than 40 Worldscale (WS) in July 2002 and WS 50 in July 2003, jumped up to a far higher average in the mid-100 WS range in July 2004. According to Poten & Partners, the factors which have put upward pressure on the VLCC, Aframax and Suezmax market have been increased oil demand by the developing economies, especially India and China.

Since transportation costs are a component added cost to the oil, their prediction is important to forecasting the all-in cost of oil at the port of debarkation. The current study demonstrates that the variation of tanker rates is due to the price of oil carried, and 40% is due to other factors, thus it can be observed that excluding seasonal periods of low tanker demand due to refinery maintenance there has been a general increase in tanker rates consistent with the price of oil.

Other factors which have impacted the pricing of the oil and tank ships over the past few years include the strength of the US economy, increasingly turbulent weather including the disruption of Gulf Port facilities by a series of hurricanes such as Hurricanes Katrina, Charles, Frances and Ivan, the reduction of Iraqi oil

production due tc
disruptions in Nige
legal problems of Y
On the oil side, w
just the first and sec
in 14 years, at 82.2
data, with demand
A complete pictu
would include refer
October of 2004, VI
fixture activity was
was experiencing ar
demonstrated that t
the change in expo
More specifically, t
exports generated a
importance of oil in
Kavussanos [16-
conditional means c
is high during and j
the, the 1973–1974
Iraq. He finds a pos
freight rates for lar
indicate that there i
These findings ar
level of crude oil pri
demand for importe
sea transportation
Alizadeh and Nomil
between freight rate
that freight rates ar
This study looks
demand for oil and t
that an upward shift
shift in the demand
capacity. A factor c
is elastic the deman
that expectation fai
proven to be inelast

3. The data

We focus on the sp
Mexico. The sampl
2 January 2006. We
which yields a total
acronyms, descripti
The West Africa-
was obtained fron

production due to hostilities there, political instability in Venezuela, supply disruptions in Nigeria, and the reduction of Russian oil production owing to the legal problems of Yukos and its CEO.

On the oil side, worldwide oil demand is the highest it has ever been in 10 years. In just the first and second quarters of 2004, worldwide oil production was at its highest in 14 years, at 82.2 million bpd, according to Energy Information Administration data, with demand reaching 82.5 million bpd in the fourth quarter.

A complete picture of the factors that determine the variability of tanker prices would include references to oil exports, particularly from the Arabian Gulf (AG). In October of 2004, VLCC rates were at a historical high of WS 220, and AG/East and fixture activity was also up 33% since 2002, while at the same time, the oil industry was experiencing an upward shift in oil prices to $55 per barrel. The Poten study demonstrated that the run up in Aframax rates in 2004 correlated with the increase in the change in export shipments in barrels per day change from the Arabian Gulf. More specifically, they concluded that a million barrels per day change in AG exports generated a 25 point change in VLCC rates. Poten [15] also emphasize the importance of oil inventories and tanker rates.

Kavussanos [16–18] provides a theoretical framework for determining the conditional means of freight and time charter rates. He demonstrates that volatility is high during and just after periods of large external shocks to the industry, such as the, the 1973–1974 and 1980–1981 oil crises, and the 1990 invasion of Kuwait by Iraq. He finds a positive relation between coefficients of variation and size such that freight rates for larger tankers show higher variations than for smaller size ones indicate that there is elasticity with size of tanker.

These findings are consistent with empirical studies which link freight rates to the level of crude oil prices in the US [19]. Mayr *et al.* [19] observed that the increase in demand for imported crude oil, such as Brent and Bonny, increased the demand for sea transportation and also had a beneficial impact on the level of freight rates. Alizadeh and Nomikos [20] find evidence for the existence of a long-run relationship between freight rates and oil prices in the US. However, they do not find evidence that freight rates are related to physical crude and WTI future price differentials.

This study looks at how the oil tanker prices have responded to the unprecedented demand for oil and the related record high oil prices. In this environment, we observe that an upward shift in the demand for oil causes increased oil prices and an upward shift in the demand for tanker capacity, causing an increase in the price for tanker capacity. A factor complicating the study is that while the demand for most products is elastic the demand for oil is inelastic. Normally when prices rise volume falls, but that expectation fails because demand for oil in this macro-environment has been proven to be inelastic.

3. The data

We focus on the spot oil tanker market between West African and the US Gulf of Mexico. The sample period for our analysis is from 16 January 1998 through 2 January 2006. We use the last trading closing in each week on the Baltic exchange which yields a total of 409 observations. Table 1 provides a list of the data series with acronyms, descriptions, units and sources.

The West Africa–US Gulf Tanker spot price on the World Scale index (BDTI4) was obtained from the Baltic Exchange. The Baltic Exchange reports the

Table 1.

Variable name	Description	Units	Source
LBDTI4	Log Baltic Dirty Tanker Index TD4: 260 000mt, West Africa to US Gulf	Index	Baltic Exchange
LRCLC3	Log Cushing, Ok Crude Oil Future Contract 3	$/Barrel	NYMEX Futures prices
LRWTC	Log West Texas Intermediate Spot Price	$/Barrel	NYMEX
LWCESTUS1	Log US Weekly Crude Oil Ending Stocks Excluding SPR	1000s of Barrels	EIA
SP_WTI3	Spread between WTI Spot Price and 3-mo Future Contract	$/Barrel	NYMEX
WCESTUS1	U.S. Weekly Crude Oil Ending Stocks Excluding SPR	1000s of Barrels	EIA

Note: A capital "D" in the beginning of a variable means that it has been transformed into natural logarithms.

transactions from a number of different indices for the tanker market. The base year for this index is 1998. The West Texas intermediate crude spot price (RWTC) and 3-month futures contract rates (RCLC3) in dollars per barrel were obtained from Bloomberg, the New York Mercantile Exchange, and the Energy Information Agency. The US weekly petroleum inventories in 1000s of barrels (WCESTUS1) are provided by the Energy Information Agency. Unless otherwise indicated, we have transformed all series into natural logarithms for the analysis.

Figure 1 charts the three price series. The first chart is the Baltic Dirty Tanker Index. Spot prices were stagnant and falling in 1989 and 1999. They tripled in 2000 before falling to their previous level; There is a 9/11 effect, which lasts until about the fourth quarter of 2002. Then spot prices begin a roller-coaster ride with cycles of near tripling and falling in prices. Prices peaked in November 2004. These peaks coincided with periods when OECD commercial inventories were below their 5-year average band. Forward cover, days' supply dropped below 50 days in these periods. The volatility of prices appears to have increased in this period. It appears that at the end of the 1990s, oil demand was depressed by recessionary economic conditions in Western Europe and Japan, compounded by the increasing calls for using alternative energy sources (nuclear power, hydroelectric power, coal). Subsequently, oil prices increased on the basis of a large shift in demand for oil imports by industrializing China and India and heightened demand by the US. The increased demand effect was compounded by oil supply disruptions and shortfalls in Venezuela, Nigeria and later the invasion and occupation of Iraq.

The second and third charts show the WTI spot price and the 3-month contract price. We observe similar patterns in the movements in oil prices and tanker price. The collapse of oil prices is seen in 1998 followed by a gradual rise through 2000. Who can recall oil prices at $11–$12/barrel in January through March of 1999? Prices had recovered to the $25 to $30 range by the end of 2000. There is a collapse in prices following 9/11 to about $20 through early 2002. Then they rise to above $30 and have peak in the winter of 2003 when inventories were critical. Prices then began the climb to above $50 in October 2004.

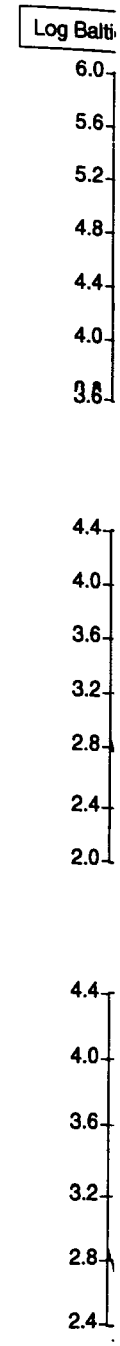

Figure 1.

Since the Americ
a steady increase in o
Middle East). Unce
a hallmark of the oil

	Source
	Baltic Exchange
	NYMEX
	Futures prices
	NYMEX
:els	EIA
	NYMEX
:els	EIA

ı transformed into natural

narket. The base year
ɔt price (RWTC) and
l were obtained from
Energy Information
'els (WCESTUS1) are
se indicated, we have

: Baltic Dirty Tanker
. They tripled in 2000
h lasts until about the
er ride with cycles of
er 2004. These peaks
ere below their 5-year
days in these periods.
It appears that at the
'onomic conditions in
s for using alternative
bsequently, oil prices
ɔrts by industrializing
reased demand effect
enezuela, Nigeria and

the 3-month contract
ices and tanker price.
ıal rise through 2000.
ugh March of 1999?
There is a collapse in
hey rise to above $30
cal. Prices then began

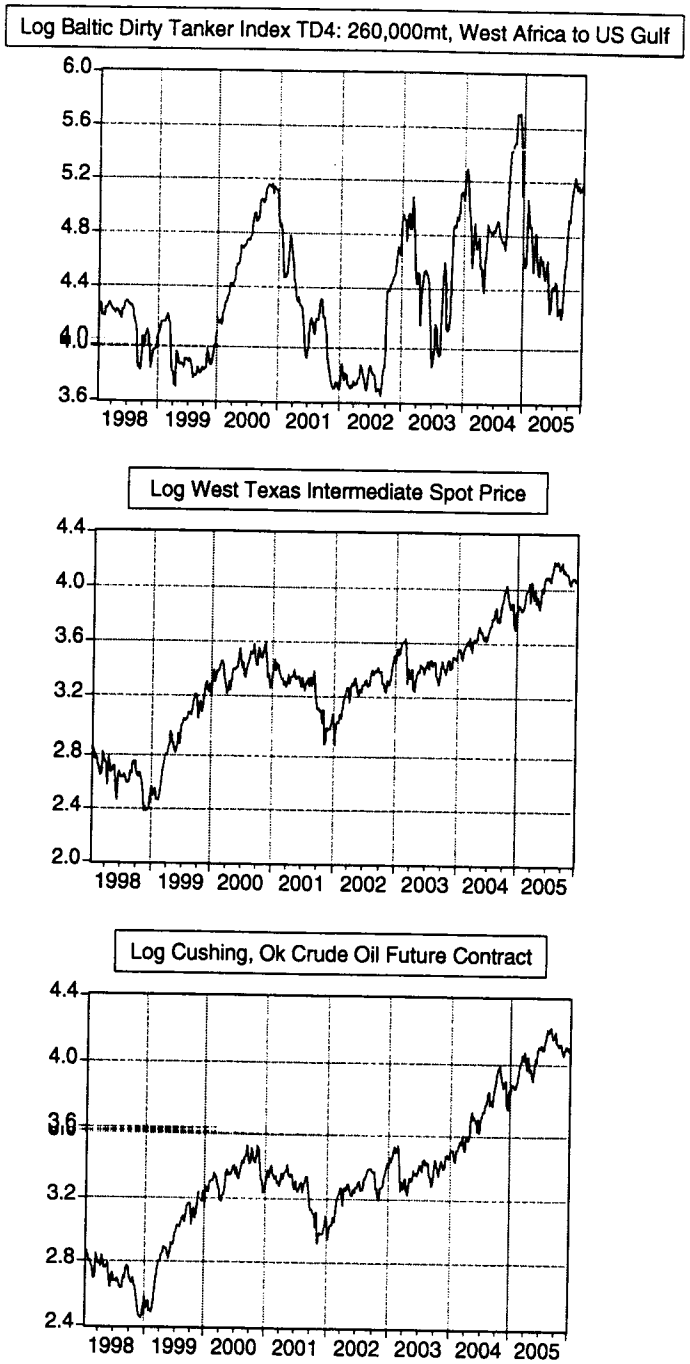

Figure 1.

Since the American invasion and occupation of Iraq in 2002, there has been a steady increase in oil prices because of shortfalls in Iraqi oil (destabilization of the Middle East). Uncertainty about the stability and security of supply has been a hallmark of the oil market since 2000. Exacerbating the impact of Iraq has been

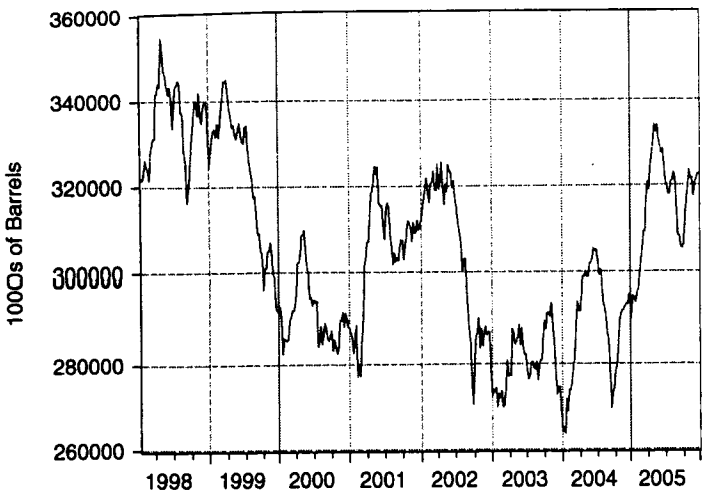

Figure 2. US weekly crude oil ending stocks excluding SPR.

a series of exceptionally destructive hurricanes, especially in the US Gulf Region, an unprecedented tsunami which especially impacted the oil country of Indonesia, and production cutbacks occasioned by the arrest of the CEO of Russia's largest oil company, Yukos. The equilibrium price of oil also reflects the interaction of supply and demand. Supply is the result of production from existing wells plus intensified extraction from those wells plus production of new wells.

Figure 2 contains the US Weekly Inventory measure. Through mid 1999 inventories were above 330MB. They decline dramatically and remain about 290 MB through 2000. The recession in 2001–2002 may have lead to the expansion of inventories back up to about 310 MB. Economic growth domestically and internationally and higher prices may have lead to the decline in inventories back under 300 MB in 2003 and 2004. Speculators and the convenience yield led to the increase in inventories through 2005. Prices had risen from $45 to over $65 per barrel and the futures market was geared toward higher prices.

In Figure 3, a comparison is given of the trend and dynamics for West Africa–US Gulf Tanker Rates and the West Texas Intermediate Spot Price, which are graphically displayed. The former is on the left-hand scale and the later is on the right-hand scale. The two prices appear to move together cyclically and in relative levels following the discussion above. There appears to be far greater volatility in the Baltic Dirty Tanker Index than oil prices. This might be driven by other demand and supply factors. One example might demand side effects from actual inventory levels and (future) desired inventory levels. Second, on the supply side there is tanker capacity. This depends on current capacity plus added new tankers minus older tankers scrapped. We were unable to obtain a measure or proxy of capacity, so our results are conditioned upon this fact.

In the earlier part of the period, the two rates fluctuate reflecting the impact of higher oil prices on tanker prices which makes sense from the viewpoint that higher oil prices would generally reflect to some degree a shortage of tanker capacity for the demand level. However, after 2002, the relationship diminishes as oil prices increase steadily while tanker rates are highly volatile. It may be that by 2002 the tanker

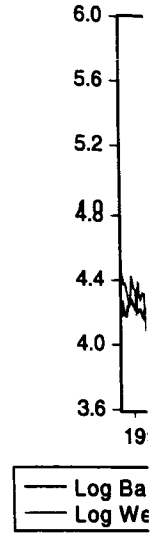

Figure 3.

industry had adjuste
much higher platea
including some majo
market having ente
heightened Middle E
in maritime insuranc
Persian Gulf area, w

Figure 4 contains
and US Weekly Pet
to 2005. There is a
and US Gulf tanke
when inventories ar
the tanker spot rate
current and future c
which translates pa
process based on ch
can raise their rates
supply and also th
because of the will
between the tanker
between tanker pric
mean higher prices f
the oil price. That
conversely, high oil
imported using tan
prices.

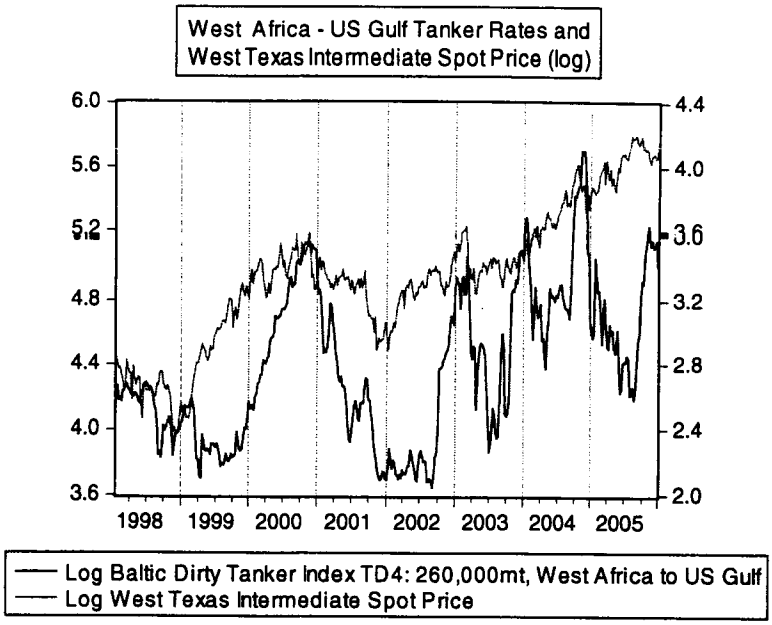

Figure 3.

industry had adjusted more slowly than the oil market. Oil prices had moved to a much higher plateau, and the tanker market entered a period of high volatility including some major price cuts. Additional upward pressure on tanker rates was the market having entered a period of higher level of political/military risks due to heightened Middle Eastern instability, pushing up the rates was a significant increase in maritime insurance rates due to the perception of heightened risk, especially in the Persian Gulf area, where tankers would naturally congregate.

Figure 4 contains a chart of the West African–US Gulf of Mexico tanker rates and US Weekly Petroleum inventories are shown on a log basis for the period 1998 to 2005. There is a strong and consistent inverse relationship between West Africa and US Gulf tanker rates and US weekly petroleum inventories. We observe that when inventories are high, tanker spot rates are low, and, when inventory is down, the tanker spot rate goes up. Lower inventories, would suggest upward pressure on current and future oil prices. Low inventories can indicate a strong demand for oil which translates partially into higher tanker rates. Tanker rates reflect an auction process based on changing supply and demand. When oil prices are high the tankers can raise their rates because the higher oil price in part reflects a scarcity of tanker supply and also the tanker price is essentially inelastic in time of high demand because of the willingness of shippers to pay the higher rates. The relationship between the tanker rates and inventories is more apparent than the relationship between tanker prices and WTI spot prices. This could be because lower inventories mean higher prices for tankers because the inventory level is an inverse surrogate for the oil price. That is, low inventories are synonymous with high oil prices and conversely, high oil inventories are synonymous with low oil prices. Since most oil is imported using tankers, a high oil price implies low inventories and high tanker prices.

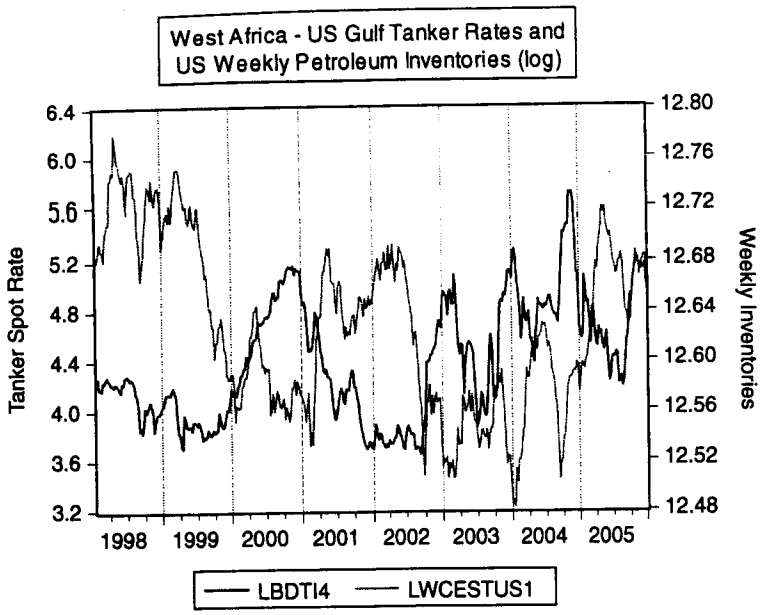

Figure 4.

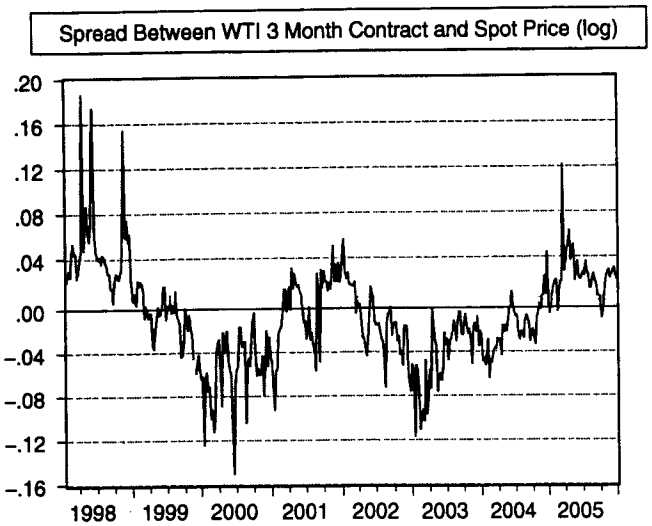

Figure 5.

Figure 5 shows the spread between the natural logarithms of the WTI spot price and the 3-month contract price. Alizadeh and Nomikos [20] have used this variable as a cost of carry or convenience yield measure. It captures the interest rate costs, storage costs and transportation costs to the delivery point. We interpret this more as convenience yield measure in that US refiners are willing to hold inventory. Increases in the spread might suggest higher prices are expected or inventory build-ups are desired over the next few months. This leads to an increase in oil demand pushing up Tanker rates. Figure 6 demonstrates this relationship.

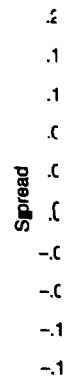

Figure 6. Spread W
inventories (log).

4. Econometric mo
We employ the gene
The general-to-spec
econometrics. It att
parametric relations
the findings of prev
sense. Rather than
which alternative th
The approach be
variables and dyna
hypothesis is consid
down by testing for
The first step inv
series. We look at p
order of integratio
system. This step i
including residual d
examine the system
integrated of the sa
series which are int
relations and test fo
correction model of
performed and econ

5. Empirical result
5.1. *Time series pr*
Campbell and Perr
series contain unit

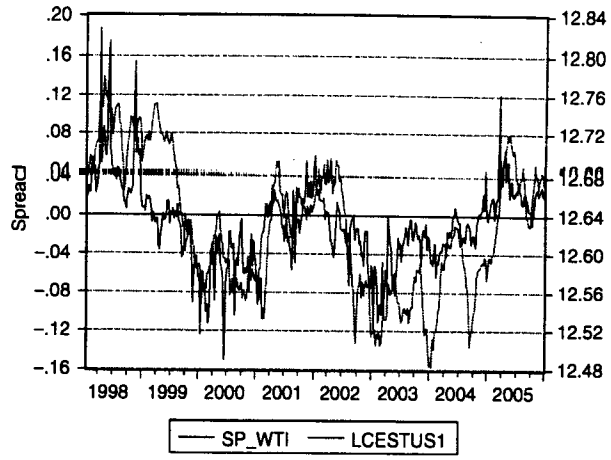

Figure 6. Spread WTI 3-month contract and WTI spot price with US weekly petroleum inventories (log).

4. Econometric modelling issues

We employ the general-to-specific modeling approach advocated by Hendry [21–23]. The general-to-specific modelling approach is a relatively recent strategy used in econometrics. It attempts to characterize the properties of the sample data in simple parametric relationships which remain reasonably constant over time, account for the findings of previous models, and are interpretable in an economic and financial sense. Rather than using econometrics to illustrate theory, the goal is to 'discover' which alternative theoretical views are tenable and test them scientifically.

The approach begins with a general hypothesis about the relevant explanatory variables and dynamic process (i.e. the lag structure of the model). The general hypothesis is considered acceptable to all adversaries. Then the model is narrowed down by testing for simplifications or restrictions on the general model.

The first step involves examining the time series properties of the individual data series. We look at patterns and trends in the data and test for stationarity and the order of integration. Second, we form a vector autoregressive regression (VAR) system. This step involves testing for the appropriate lag length of the system, including residual diagnostic tests and tests for model/system stability. Third, we examine the system for potential cointegration relationship(s). Data series which are integrated of the same order may be combined to form economically meaningful series which are integrated of lower order. Fourth, we interpret the cointegrating relations and test for weak exogeneity. Based on these results, a conditional error correction model of the endogenous variables is specified, further reduction tests are performed and economic hypotheses tested.

5. Empirical results

5.1. *Time series properties of the individual series*

Campbell and Perron [24] provide rules (of thumb) for investigating whether time series contain unit roots. To begin, we estimate the following three forms of the

augmented Dicke–Fuller (ADF) test where each form differs in the assumed deterministic component(s) in the series:

$$\Delta y_t = \alpha_i\, y_{t-1} + \sum_{i=1}^{P} \gamma_i \Delta y_{t-i} + \varepsilon_t; \quad \text{no constant and trend}$$

$$\Delta y_t = \alpha_0 + \alpha_i\, y_{t-1} + \sum_{i=1}^{P} \gamma_i \Delta y_{t-i} + \varepsilon_t; \quad \text{constant only}$$

$$\Delta y_t = \alpha_0 + \alpha_i\, y_{t-1} + \alpha_2 * t + \sum_{i=1}^{P} \gamma_i \Delta y_{t-i} + \varepsilon_t; \quad \text{constant and trend}$$

The ε_t is assumed to be a Gaussian white noise random error; and $t = 1, \ldots, T$ (the number of observations in the sample) is a term for trend. The number of lagged differences, P, is chosen to ensure that the estimated errors are not serially correlated based on the AIC statistic.

The results from the unit root tests are found in Table 2 and Table 3. The first column lists the five variables under analysis. The second and third columns report the test results including a constant only and the constant and trend. A model with no constant and trend is not reported because the constant and or trend were significant. We find that all five series are I(1) processes. We cannot reject the null of I(1) against I(0) or stationarity. The spread variable appears to reject the null hypothesis at the 5% level with only a constant. However, it does not reject the null when a trend is included in the model. The trend does add explanatory power the equation, so we conclude it is I(1). Nominal price and financial series are found to be non-stationary in their first differences or they are I(2). We report the tests for these hypotheses in Table 2. In all cases, the null hypothesis of I(2) is rejected. Thus we

Table 2. Augmented Dickey–Fuller test for unit root in levels t-statistics with lag selection based on AIC for sample 16 February 1998 to 2 January 2006.

Variable	Constant	Constant and trend
LBDTI4	−2.427 (2)	−3.048 (2)
LWTI	−0.071 (6)	−2.086 (6)
LWTI3	−0.517 (3)	−2.156 (3)
LWESTUS1	−2.570 (2)	−2.379 (2)
SP_WTI3	−3.181 (4)*	−2.565 (6)

Table 3. Augmented Dickey–Fuller test for unit root in first differences t-statistics with lag selection based on AIC for sample 16 February 1998 to 2 January 2006.

Variable	Constant	Constant and trend
DLBDTI4	−13.26 (1)**	−13.25 (1)**
DLWTI	−9.059 (6)**	−9.367 (5)**
DLWTI3	−9.047 (6)**	−9.060 (6)**
DLWESTUS1	−11.98 (1)**	−12.02 (1)**
SP_WTI3	−12.28 (5)**	−12.29 (5)**

Note: T = 400 observations;
Critical values: constant 5% = −2.87, 1% = −3.45, constant and trend 5% = −3.42, 1% = −3.98.

conclude that the tanl
spread between the '
measure are I(1) or fi

5.2. *Specification of*
The choice of the va
causal relationship b
West Texas intermed
(RCLC3), and the da
analysed using a vec
statistical model and
run. The four variabl

$$\begin{bmatrix} \ln BDTI4_t \\ \ln RCLC3_t \\ \ln WTI_t \\ \ln WCESTUS1_t \end{bmatrix}$$

$$A(L) = A_1 L + A_2 L$$

The price series
logarithms to (partiall
are included in each e
are assumed to be
expression $A(L)$ is a l
used in the VAR. The
the ith lag.

The number of l
methodology is to st
necessary. Estimate tl
stability of the model
assumption of white
over-parameterized m
statistical model of th
the fewest number of

5.3. *Lag length selec*
The selection criteri
parameterizing the r
Schwartz Criterion (
Information Criterior
information similar tc

conclude that the tanker spot price, WTI spot price, WTI 3-month contract price, the spread between the WTI spot and future price, and the weekly crude inventory measure are I(1) or first difference stationary.

5.2. *Specification of the VAR model*

The choice of the variables is based on the analysis of the data in Section 2. The causal relationship between the West Africa–US Gulf Tanker spot price (BDTI4), West Texas intermediate crude spot price (RWTC), 3-month futures contract rates (RCLC3), and the days supply of US weekly petroleum inventories (WCESTUS1) is analysed using a vector autoregression model or system, VAR. We estimate the statistical model and test for dynamic relationships in both the short-run and long-run. The four variable VAR can be specified as:

$$\begin{bmatrix} \ln BDTI4_t \\ \ln RCLC3_t \\ \ln WTI_t \\ \ln WCESTUS1_t \end{bmatrix} = A(L) \begin{bmatrix} \ln BDTI4_t \\ \ln RCLC3_t \\ \ln WTI_t \\ \ln WCESTUS1_t \end{bmatrix} + B \begin{bmatrix} constant \\ timetrend_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{t,1} \\ \varepsilon_{t,2} \\ \varepsilon_{t,3} \\ \varepsilon_{t,4} \end{bmatrix}$$

$$A(L) = A_1 L + A_2 L^2 + A_3 L^3 + \ldots + A_p L^p$$

The price series and inventory measure have been transformed to natural logarithms to (partially) address heteroskedasticity issues. A constant and trend term are included in each equation; their role will be modified later. The two error terms are assumed to be white noise and can be contemporaneously correlated. The expression $A(L)$ is a lag polynomial operator indicating that p lags of each price is used in the VAR. The individual A_i terms represent a 4×4 matrix of coefficients at the ith lag.

The number of lags to use in model at the beginning is unknown. The methodology is to start with an initial trial of p lags assumed to be more than necessary. Estimate the VAR and test for serial correlation, heteroskedasticity and stability of the model. The idea or goal is to obtain results that appear close to the assumption of white noise residuals. A large number of lags is likely to produce an over-parameterized model. However, any econometric analysis needs to start with a statistical model of the data generating process. Parsimony is achieved by testing for the fewest number of lags that meet can explain the dynamics in the data system.

5.3. *Lag length selection*

The selection criteria for the appropriate lag length are used to avoid over-parameterizing the model and produce a parsimonious model. The Bayesian Schwartz Criterion (BSC), the Hannan–Quinn Criterion (HQ), and the Akaike Information Criterion (AIC) are often used as alternative criterion. They rely on information similar to the Chi-Squared tests and are derived as follows:

$$BSC = \log\left(Det\hat{\Sigma}\right) + 2 * c * \log(T)T^{-1}$$

$$HC = \log\left(Det\hat{\Sigma}\right) + 2 * c * \log(\log(T)) * T^{-1}$$

$$AIC = \log\left(Det\hat{\Sigma}\right) + 2 * c * T^{-1} \tag{1.1}$$

Table 4. VAR lag order selection criteria.

Lag	Log L	LR	FPE	AIC	SC	HQ
0	1003.089	NA	7.66e–08	−5.033195	−4.993055	−5.017294
1	3210.852	4359.915	1.23e–12	−16.07482	−15.87412*	−15.99532
2	3245.964	68.63132	1.11e–12	−16.17110	−15.80984	−16.02799*
3	3262.293	31.58814	1.11e–12*	−16.17276*	−15.65093	−15.96605
4	3270.147	15.03614	1.16e–12	−16.13172	−15.44934	−15.86141
5	3284.555	27.29191	1.17e–12	−16.12370	−15.28075	−15.78979
6	3289.466	9.202899	1.24e–12	−16.06784	−15.06433	−15.67032
7	3304.917	28.64444	1.24e–12	−16.06507	−14.90100	−15.60395
8	3318.394	24.71382	1.26e–12	−16.05236	−14.72773	−15.52763
9	3330.613	22.16143	1.28e–12	−16.03332	−14.54812	−15.44499
10	3337.315	12.01908	1.34e–12	−15.98647	−14.34072	−15.33454

Notes: Sample: 26 January 1998 1/02/2006;
Included observations: 397;
The VAR system includes four variables: LBDTI4, LRCLC3, LRWTI and LWCESTUS1. There is a constant and trend in the VAR as well;
*indicates lag order selected by the criterion;
LR: sequential modified LR test statistic (each test at 5% level);
FPE: Final prediction error;
AIC: Akaike information criterion;
SC: Schwarz information criterion;
HQ: Hannan–Quinn information criterion.

Intuitively, the log determinant of the estimated residual covariance matrix will decline as the number of regressors increases, just as in a single equation ordinary least squares regression. It is similar to the residual sum of squares or estimated variance. The second term on the right-hand side acts as a penalty for including additional regressors (c) which are scaled by the inverse of the number of observations (T). It increases the statistic. Once these statistics are calculated for each lag length, the lag length chosen is the model with the minimum value for the statistics respectively. The three tests do not always agree on the same number of lags. The AIC is biased towards selecting more lags than is actually needed; this is not necessarily bad.

Table 4 shows results for the three tests. The maximum possible lag length considered was ten (weeks). The first column gives the lag length for each test and the last three columns of the table provide the test statistics. In this case the choice is ambiguous, because the three tests reveal only one lag is needed by the SC, two lags with the HQ and three lags with the AIC. Further examination found serial correlation at one lag. We selected three lags for analysis to be conservative.

The residual diagnostics are examined in Figure 7 and Table 5. Figure 7 has three columns and four rows one for each equation. The columns represent the estimated residuals, a histogram with normal distribution, and the autocorrelation and partial autocorrelations respectively. There appear to be periods with very large errors or outliers in the three price series. Also, there appears to be an increase in the variance for the Tanker rates (LBDTI4, first column and first row). This leads to relatively sharp peaks in the frequency distributions and fat tails which are the norm with financial or price series. There does not appear to be any serial correlation in all four equations. Table 5 provides the residual diagnostic tests from the 4-variable system with three lags. We report both the individual equation tests and the system or

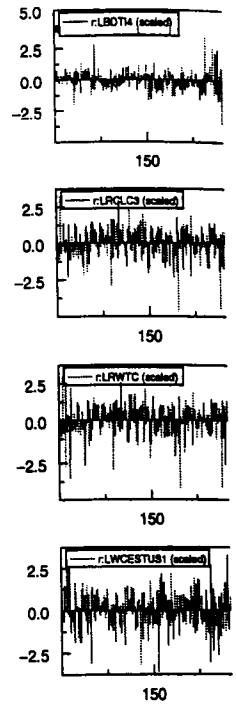

Figure 7.

Table

Skewness
Excess kurtosis
Skewness (transformed
Excess kurtosis (transfc
J-B test
$Chi^2(2)$=

Vector Normality test:
AR 1-2 test:
F(2,392)=
Portmanteau test with

Vector Portmanteau(10
Hetero test:
F(26,367)=

Vector hetero test: F(26
ARCH 1–1 Test:
F(1,392)

Notes: Sample: 26 Janua
Included observations: 3
The VAR system includ
constant and trend in th
Significant at 5% (*) an

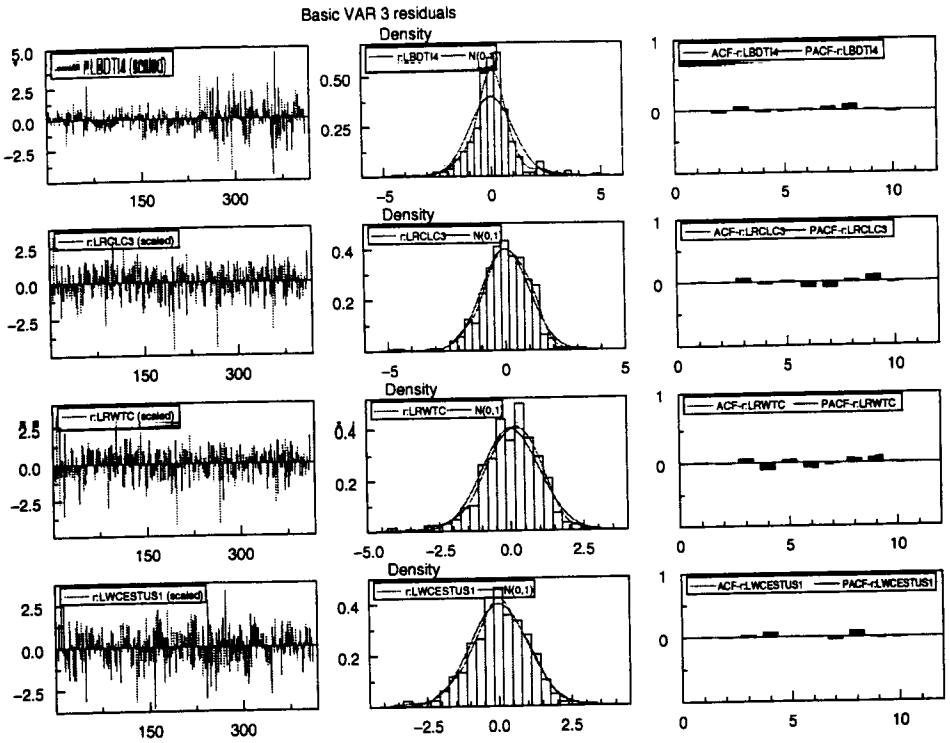

Figure 7.

Table 5. Residual diagnostic tests normality test for residuals.

	LBDTI4	LRCLC3	LRWTI	LWCESTUS1
Skewness	0.037708	−0.30912	−0.91646	−0.28527
Excess kurtosis	6.9724	4.3355	7.7874	3.7658
Skewness (transformed)	0.31632	−2.5386	−6.6543	−2.3499
Excess kurtosis (transformed)	11.572	4.0823	6.7315	2.3258
J-B test	135.04	33.449	28.398	10.788
$Chi^2(2)$=	[0.0000]**	[0.0000]**	[0.0000]**	[0.0045]**
Vector Normality test: $Chi^2(8) = 257.64$ [0.0000]**				
AR 1-2 test:	2.1396	0.77893	0.78208	0.66243
F(2,392)=	[0.1191]	[0.4596]	[0.4582]	[0.5162]
Portmanteau test with 10 lags				
	6.22129	11.4148	13.5525	6.95853
Vector Portmanteau(10): 157.931				
Hetero test:	2.9969	0.66306	1.1945	1.3795
F(26,367)=	[0.0000]**	[0.8968]	[0.2367]	[0.1048]
Vector hetero test: $F(260\ 3377) = 1.5772$ [0.0000]**				
ARCH 1–1 Test:	6.1768	1.2373	6.3164	0.77604
F(1,392)	[0.0134]*	[0.2667]	[0.0124]*	[0.3789]

Notes: Sample: 26 January 1998;
Included observations: 397;
The VAR system includes four variables: LBDTI4, LRCLC3, LRWTI and LWCESTUS1. There is a constant and trend in the VAR as well;
Significant at 5% (*) and 1% (**).

SC	HQ
-4.993055	−5.017294
-15.87412*	−15.99532
-15.80984	−16.02799*
-15.65093	−15.96605
-15.44934	−15.86141
-15.28075	−15.78979
-15.06433	−15.67032
-14.90100	−15.60395
-14.72773	−15.52763
-14.54812	−15.44499
-14.34072	−15.33454

ıd LWCESTUS1. There is a

covariance matrix will
ngle equation ordinary
ıf squares or estimated
ı penalty for including
se of the number of
stics are calculated for
minimum value for the
ın the same number of
actually needed; this is

ım possible lag length
ɜth for each test and the
. this case the choice is
ıed by the SC, two lags
mination found serial
be conservative.
ıle 5. Figure 7 has three
represent the estimated
ɔcorrelation and partial
ith very large errors or
increase in the variance
This leads to relatively
ich are the norm with
ıl correlation in all four
n the 4-variable system
ɜsts and the system or

vector tests. Column one explains the test in each row. The next four columns contain the statistics for LBDTI4, LRCLC3, LRWTI and LWCESTUS1 respectively. The first set of rows look at whether the estimated residuals exhibit normality. They confirm the visual observations from the figure. There does not appear to be a problem with skewness, but there is problem with kurtosis which results in the rejections of the Jarque–Bera tests. The autocorrelation tests and Portmanteau tests by equation and for the system do not reject the null of no autocorrelation. The tests for homoskedasticity are next. Again, the visual evidence is confirmed. We find that the null of homoskedasticity for the Tanker rate equation is rejected, but not for the other equations. The final test is for the null of no conditional heteroskedasticity at lag one. Tanker rate and the oil spot price appear to have an ARCH process, but this result may be due to the large outliers.

5.4. *Granger causality tests*

Table 6 shows the Granger causality tests for this 4-variable model. Each of the 4 variables appears to have explanatory power for one or more of the other variables in the system. The effects are direct but often complex and indirect. In the first equation, it appears that neither of the crude prices provides explanatory power for the Tanker rate and inventories only at the 10% level. However, if all these series are omitted for the equation, there is a loss of power at nearly 1%. There must be a multifaceted relationship between these series leading to an explanation of tanker rates. Futures contracts appear to be influenced by Tanker rates and inventories at 5% and 1% levels respectively. The WTI spot price is explained by past values of all three series. Inventories probably contain the information from spot prices and future prices. Financial theory would suggest that efficient markets already use the spot price. Spot prices are explained by all three other series. Inventories appear to be explained by the three price series at about the 5% level individually and jointly. The strength of this result was somewhat surprising, because we hypothesized that real supply and demand variables are important in explaining movements in inventories.

Table 6. VAR pairwise Granger causality or block exogeneity Wald tests exclusion restrictions.

Equations	LBDTI4	LRCLC3	LRWTI	LWCESTUS1	All
LBDTI4		3.985	4.496	7.451	20.902
		0.263	0.213	0.059*	0.013**
LRCLC3	7.981		1.185	6.470	15.279
	0.046**		0.757	0.091*	0.084*
LRWTI	9.553	16.806		13.146	34.884
	0.023**	0.001***		0.004***	0.000***
LWCESTUS1	7.285	7.684	8.033		18.298
	0.063*	0.053*	0.045**		0.032**

Notes: Sample: 26 January 1998 1/02/2006;
Included observations: 397;
The VAR system includes four variables: LBDTI4, LRCLC3, LRWTI and LWCESTUS1. There is a constant and trend in the VAR as well;
The Chi-square tests are reported in each cell with their associated p-values. There are three restrictions in the four columns and nine restrictions in the last column;
Significant at 10% (*), 5% (**) and 1% (***).

Prices are no doubt correlated with those variables and that may explain the strong relationship.

5.5. *The cointegration analysis of the vector autoregression model*

In this section the Johansen procedure is applied to test for the presence of cointegration. The VAR model in levels can be linearly transformed into one in first differences.

$$\begin{bmatrix} \Delta \ln BDTI4_t \\ \Delta \ln RCLC3_t \\ \Delta \ln WTI_t \\ \Delta \ln WESTUS1_t \end{bmatrix} = \Pi \begin{bmatrix} \ln BDTI4_{t-1} \\ \ln RCLC3_{t-1} \\ \ln WTI_{t-1} \\ \ln WESTUS1_{t-1} \end{bmatrix} + \Gamma(L) \begin{bmatrix} \Delta \ln BDTI4_{t-1} \\ \Delta \ln RCLC3_{t-1} \\ \Delta \ln WTI_{t-1} \\ \Delta \ln WESTUS1_{t-1} \end{bmatrix}$$

$$+ B \begin{bmatrix} cons\tan t \\ trend_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$$

$$\text{where } \Pi = \Pi_1 + \Pi_2 - I, \quad \Gamma_1 = -\Pi_2 - \Pi_3 - \ldots - \Pi_p,$$
$$\Gamma_2 = -\Pi_3 - \Pi_4 - \ldots - \Pi_p, \ldots, \quad \Gamma_{p-1} = -\Pi_p$$
$$\varepsilon \sim (0, \Omega),$$

The crux of the Johansen test is to examine the mathematical properties of the Π matrix which contains important information about the dynamic stability of the system. Intuitively, the Π matrix above is an expression relating the levels of the endogenous variables in the system.

Engle and Granger [25] demonstrate the one-to-one correspondence between cointegration and error correction models. Cointegrated variables imply an error correction (ECMs) representation for the econometric model and, conversely, models with valid ECMs impose cointegration. Evaluating the number of linearly independent equations in Π is done by testing for the number of non-zero characteristic roots, or eigenvalues, of the Π matrix, which equals the number of linearly independent rows [26]. The matrix can be rewritten as the product of two full column vectors, $\Pi = \alpha\beta'$.

The matrix β' is referred to as the cointegrating vector and α as the weighting elements for the rth cointegrating relation in each equation of the VAR. The vector $\beta' Y_{t-1}$ is normalized on the variable of interest in the cointegrating relation and interpreted as the deviation from the 'long-run' equilibrium condition. In this context, the column α represents the speed of adjustment coefficients from the 'long-run' or equilibrium deviation in each equation. If the coefficient is zero in a particular equation, that variable is considered to weakly exogenous and the VAR can be conditioned on that variable. Weak exogeneity implies that the beta terms or long-run equilibrium relations do not provide explanatory power in a particular equation. If that is true, then valid inference can be conducted by dropping that equation from the system and estimating a conditional model.

Cointegration tests are for long-run interactions capturing fundamental relationships. The question often arises as to how many observations are necessary for testing. The number observation, per se, is not much a concern. Juselius [27] explains that the question of how big the sample should be has, unfortunately, no obvious

answer—whether the sample is 'small' or 'big' is a function not only of the number of observations but also of the amount of information in the data. She emphasizes that when the data are very informative about a hypothetical long-run or cointegration relation, there might be good test properties even if the sample period is relatively short, citing the case where the equilibrium error crosses the mean line several times during the period. Campos and Ericsson [28] demonstrate similar findings in the case of Venezuela. The critical issue is the information content in the data or high 'signal-to-noise' ratio. Venezuela, like many emerging markets, has experienced large shocks such as crises in banking, deregulation, volatile oil prices, fluctuating government oil revenues and inflation. While these are serious problems and can lead to tragic events for individuals and the economy, they provide valuable information to the applied econometrician. In our empirical analysis, we are using 8 years of weekly market data, almost 400 observations. We are confident that the market fundamentals or long-run relationships are testable.

The results of the Johansen cointegration test are presented in Table 7 and are partitioned into three parts. The first part provides the test results for the null hypothesis of no cointegration. The eigenvalues of the Π matrix are sorted from largest to smallest. The tests are conducted sequentially, first examining the possibility of no cointegrating relation against the alternative that there is one cointegrating relations, and then the null of one cointegrating relation against the possibility of two cointegrating relations, e.g. essentially, these are tests of whether the eigenvalue(s) is (are) significantly different from zero. We rejected the null of no

Table 7. Johansen cointegration analysis of BDTI4 tanker prices, WTI, WTI 3-mo contract and US weekly petroleum Inventories.

Rank	Eigenvalue	Trace	p-value	Max eigen.	p-value
0	0.11563	80.35	0.001**	50.26	0.000**
1	0.04902	30.09	0.503	20.56	0.220
2	0.01395	9.53	0.936	5.75	0.954
3	0.00921	3.78	0.770	3.78	0.772

Standardized eigenvalues, beta' values and standard errors

	LBDTI4	LRCLC3	LRWTC	LWESTUS1	Trend
	1.00	−50.492	48.350	28.143	0.0102
	–	6.957	6.687	4.221	0.003

Standardized alpha coefficients and standard errors

	LBDTI4	LRCLC3	LRWTC	LWESTUS1
	−0.0088	0.0018	−0.0038	−0.0016
	0.004	0.0018	0.0023	0.0005
Weak		0.19	2.86	9.12
Exogeneity		(0.66)	(0.09)	(0.003)

Notes: Sample: 26 January 1/02/2006;
Included observations: 397;
The VAR system includes four variables: LBDTI4, LRCLC3, LRWTI and LWCESTUS1. There is a constant and trend in the VAR as well;
The weak exogeneity tests are Chi-squares with 1 degree of freedom. P-values are reported in parentheses.

cointegration or ra
rate model is rej
Max(eigenvalue) te

The second pai
BDTI4 spot tanke
for tankers on the

Spot Tanker Pric

The estimates f
signs are reported
signs. The associat
three month contr
future prices are ex
will be upward pre
crude are increasin
negative trend. E
hypothesis is that i
time easing the spc

We report hypo
the third part of th
is appropriate (an
case, the estimate i
the demand relatio
can test if the othe
variables are influe
Chi-square tests fo
significant and is w
rate. However, pa

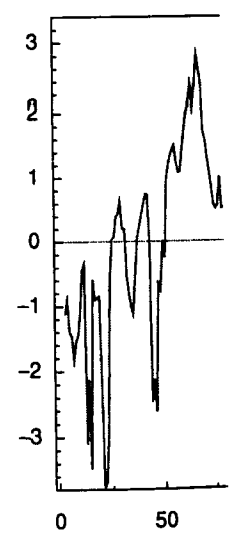

Figure 8.

cointegration or rank zero. The test for no cointegration (r = 0) in the spot tanker rate model is rejected at less than 0.01 with the Trace test (80.4) and the Max(eigenvalue) test (50.3).

The second part shows the first standardized eigenvector or β vector on the BDTI4 spot tanker rate. We interpret the cointegrating relation as demand relation for tankers on the spot market for the West Africa–US Gulf trade.

$$\textit{Spot Tanker Price}_t = 50(3\ \textit{mo. Future Price}_t - \textit{WTI Spot Price}_t) - 28\ \textit{Inventories}_t$$

The estimates for the β vector are presented in a row under each variable. The signs are reported as if the sum of the entire vector equals zero, thus the opposite signs. The associated standard errors are provided below. The β coefficients for the three month contract and WTI are roughly equal and of opposite sign. Thus, if future prices are expected to rise or the 3-month contract-spot spread is positive there will be upward pressure on tanker rates. If weekly inventories of days supply for US crude are increasing, then spot rates are falling. The cointegrating includes a small negative trend. Explaining this component is beyond the current research. One hypothesis is that it could reflect growing tanker capacity (on the spot market) over time easing the spot price. Figure 8 illustrates the error correction mechanism.

We report hypothesis tests on the α vector and the associated standard errors in the third part of the table. If the cointegrating or demand relation we have specified is appropriate (and stationary), then its own coefficient must be negative. In this case, the estimate is −0.0088 and significant. Thus, if the spot tanker rate was above the demand relation last week, the change in the spot rate this week should lower. We can test if the other α terms are significant, that is whether the equations for those variables are influenced by the cointegrating relation using the standard errors or the Chi-square tests for weak exogeneity. We find that the 3-month contract rate is not significant and is weakly exogenous with respect to the relation for the current spot rate. However, past tanker rates and inventories do help to explain the 3-month

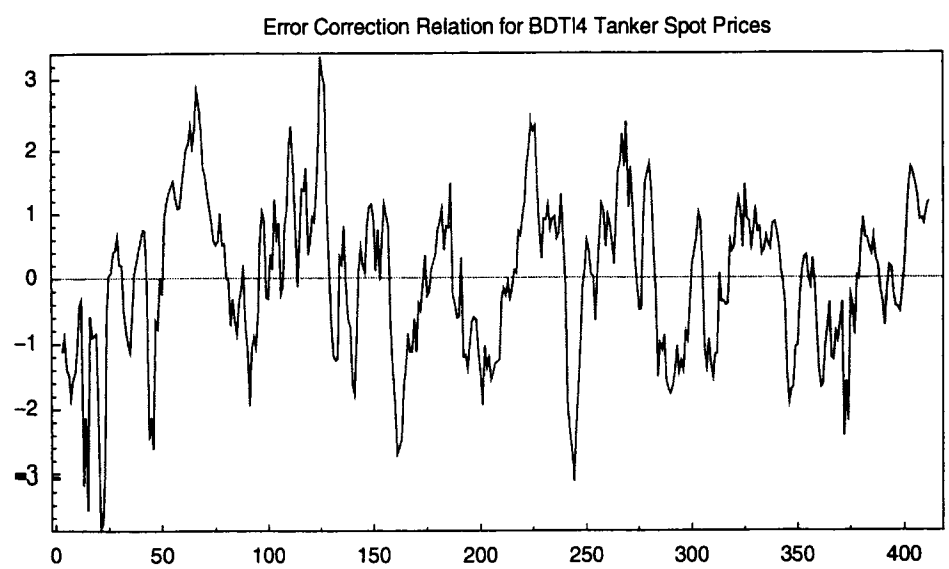

Figure 8.

contract rate in the Granger Causal sense. The WTI is negatively, but marginally related to the spot rate demand cointegrating relation with a p-value of 0.09. Inventories may be related or partially explained by the relation; the p-value is less than 0.01.

6. Discussion and conclusions

This paper examines the relationship between weekly spot tanker prices and the oil market over the past 8 years (1998–2006). The focus is on the West African and US Gulf Coast tanker market. We find that past knowledge of spot tanker rates, 3-month future contracts, spot WTI prices and the days supply of crude inventories explain current values in a Granger causal sense. In addition we are able to uncover a demand relation for tankers in the spot market using cointegration analysis. This finding may reflect the idea that the demand for tankers is a derivative for the demand for oil. If there is a strong demand for oil, there is a strong demand for tankers, so it is possible for tanker companies to raise rates. The demand determinants suggest that when the spread or 3-month Cushing futures contract is trading above the current WTI spot price there is upward pressure on spot tanker rates. In addition, when the day's supply of crude inventories increases the spot tanker rate declines. We find some feedback between the spot tanker market, current prices and inventories.

Future research can examine these interactions in several ways. One approach would be to see if similar relations are present in the other tanker markets. Second, the existence of cointegration implies we can continue the analysis in an error correction modelling framework. The demand relation can be used in a model of the changes in the spot tanker market from week to week. The error correction model can examine possible seasonal impacts and very short-term market effects. For example, tanker prices are weakest in the spring and summer and strongest in the winter. Specifically the fourth and the following first quarter of the year, which are the northern hemisphere winter months, are the priciest months for tanker rates.

Acknowledgements

The authors would like to thank Ilias D. Visvikis and participants at the International Association of Maritime Economists Conference in Sydney, Australia, July 2006. In addition, we benefitted from comments at the Energy Economics Seminar at the University of Alberta, and the Federal Forecasters Conference in Washington, DC 2008. Also, Poten & Partners assisted in obtaining data on the spot tanker markets. The authors received valuable comments and suggestions from the editor and referees.

References

1. US Energy Information Administration, 2005, *Annual energy outlook 2006 with projections to 2030*, Report #: DOE/EIA-0383(2006), Washington, DC, December.
2. Koopmans, T. C., 1939, *Tanker freight rates and tankship building* (Haarlem, The Netherlands: P.S. King & Son, Ltd).
3. Svendsen, A. S., 1958, Sea transport and shipping economics. *Weltwirtschaftliches Archiv* (Bremen: Republication for the Institute for Shipping and Logistics).
4. Zannetos, Z. S., 1966, *The theory of oil tankship rates* (Cambridge, MA: MIT Press).

5. Devanney, J. V
Maritime Press
6. Hawdon, D., 19
10, 203–217.
7. Wergerland,
Paper, No. 12,
8. Evans, J. J. an
2nd ed (Coulsd
9. Beenstock, M.,
215–225.
10. Li, J. and Parsc
Maritime Policy
11. Lyridis, D., Z.
tanker market
93–108.
12. Kavussanos, M
rate markets. *E*
13. Kumar, S., 199
presented at the
December 1995.
14. Poten & Partn
15. Poten & Partn
16. Kavussanos, M
using autoregre
Transport Revie
17. Kavussanos, M
freight markets,
University Busi
18. Kavussanos, M
Transport Econ
19. Mayr, T. and T
refining and pb
Management, 2
20. Alizadeh, A. F
between oil futu
297–316.
21. Hendry, D. F.,
Oxford Bulletin
22. Juselius, K. an
Part II. Discussi
23. Hendry, D. F
to-specific mod
25(6–7), 831–86
24. Campbell, J. Y.
should know ab
S. Fischer, Vol.
25. Engle and Gr
estimation and
26. The number of
27. Juselius, K., 20
Texts in Econon
28. Campos, J. and
expenditure in V

atively, but marginally
ith a p-value of 0.09.
tion; the p-value is less

ınker prices and the oil
ɛ West African and US
of spot tanker rates,
ɔly of crude inventories
ve are able to uncover a
:egration analysis. This
is a derivative for the
s a strong demand for
:e rates. The demand
hing futures contract is
ɔressure on spot tanker
ɔries increases the spot
: tanker market, current

ıl ways. One approach
anker markets. Second,
ıe analysis in an error
ɛ used in a model of the
error correction model
m market effects. For
.er and strongest in the
r of the year, which are
nths for tanker rates.

ıd participants at the
onference in Sydney,
mments at the Energy
ıe Federal Forecasters
:rs assisted in obtaining
aluable comments and

:nergy outlook 2006 with
ton, DC, December.
:ship building (Haarlem,

Weltwirtschaftliches Archiv
ɡistics).
ridge, MA: MIT Press).

5. DEVANNEY, J. W., 1971, *Marine decisions under uncertainty* (Centreville, MD: Cornell Maritime Press).
6. HAWDON, D., 1978, Tanker freight rates in the short and the long run. *Applied Economics*, **10**, 203–217.
7. WERGERLAND, T., 1981, Norbulk: a simulation model of bulk freight rates. Working Paper, No. 12, Norwegian School of Economics and Business Administration, Bergen.
8. EVANS, J. J. and MARLOW, P. B., 1990, *Quantitative methods in maritime economics*, 2nd ed (Coulsdon: Fairplay Publications).
9. BEENSTOCK, M., 1985, A theory of ship prices. *Maritime Policy & Management*, **12**(3), 215–225.
10. LI, J. and PARSONS, M. G., 1997, Forecasting tanker freight rates using neural networks. *Maritime Policy & Management*, **24**, 149–160.
11. LYRIDIS, D., ZACHARIOUDAKIS, P., MITROU, P. and MYLONAS, A., 2004, Forecasting tanker market using artificial neural networks. *Maritime Economics and Logistics*, **6**, 93–108.
12. KAVUSSANOS, M. and ALIZADEH-M, A., 2002, Seasonality patterns in tanker spot freight rate markets. *Economic Modelling*, **19**, 747–782.
13. KUMAR, S., 1995, Tanker markets in the 21st century: competitive or oligopolistic? Paper presented at the 1st IAME Regional Conference held at MIT, Cambridge, MA on 15 December 1995.
14. POTEN & PARTNERS, 2004, A midsummer night's dream! Report 24 July, New York.
15. POTEN & PARTNERS, 2005, Getting back to (inventory) basics? Report 29 July, New York.
16. KAVUSSANOS, M. G., 1996, Price risk modeling of different size vessels in tanker industry using autoregressive conditional heteroscedasticity (ARCH) models. *Logistics and Transport Review*, **32**(2), 161.
17. KAVUSSANOS, M. G., 1996, Measuring risk differences among segments of the tanker freight markets, Discussion Paper No. 18, Dept of Shipping, Trade and Finance, City University Business School.
18. KAVUSSANOS, M., 1996, Comparison of volatility in the dry-cargo ship sector. *Journal of Transport Economics and Policy*, **30**(1), 67.
19. MAYR, T. and TAMVAKIS, M., 1999, The dynamic relationship between paper petroleum refining and physical trade of crude oil into the United States. *Maritime Policy & Management*, **26**, 127–136.
20. ALIZADEH, A. H. and NOMIKOS, N. K., 2004, Cost of carry, causality and arbitrage between oil futures and tanker freight markets. *Transportation Research, Part E*, **40**, 297–316.
21. HENDRY, D. F., 1986, Econometric modelling with cointegrated cariables: an overview. *Oxford Bulletin of Economics and Statistics*, **48**(3), 201–212.
22. JUSELIUS, K. and HENDRY, D. F., 2000, Explaining cointegration analysis: Part I and Part II. Discussion Paper, Etima, Evanston, IL.
23. HENDRY, D. F. and KROLZIG, H.-M., 2001, Computer automation of general-to-specific model selection procedures. *Journal of Economics Dynamics and Control*, **25**(6–7), 831–866.
24. CAMPBELL, J. Y. and PERRON, P., 1991, Pitfalls and opportunities: what macroeconomists should know about unit roots. In: *Macroeconomics annual*, edited by O. J. Blanchard, S. Fischer, Vol. 6 (Cambridge, MA: MIT Press), pp. 141–201.
25. ENGLE and GRANGER, 1987, Co-integration and error correction: representation, estimation and testing. *Econometrica*, **55**(2), 251–276.
26. The number of linearly independent rows in a matrix is called the rank.
27. JUSELIUS, K., 2006, *The cointegrated VAR model: methodology and applications, Advanced Texts in Econometrics* (Oxford: Oxford University Press).
28. CAMPOS, J. and ERICSSON, N. R., 1999, Constructive data mining: modeling consumer's expenditure in Venezeula. *Econometrics Journal*, **2**(2), 226–240.