Crude Inventory Accounting and Speculation in the Physical Oil Market

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Abstract: This paper uses inventory data from financial accounts to explore whether companies involved in the physical oil market were speculating in the run-up to 2008. Using quarterly inventory data over the period 1990Q4 to 2012Q1 and a sample of 15 of the largest listed oil companies in the world, we derive an Index of Scaled Physical Inventories (ISPI). We find declining ISPI up to the early 2000s is consistent with firms minimizing inventory for efficiency sake; then ISPI starts to increase, suggesting physical inventories could have contributed to the run-up in oil prices between 2003 and 2008. Highlighting heterogeneity in inventory behaviors amongst the large oil companies, the structural break test on the ratio of inventory to sales and the days to sales for individual companies shows that five companies had positive structural breaks during the speculation period, while the other companies had no or negative structural breaks. Contrary to declining inventory expectations due to a tightening oil market, the positive structural breaks suggest speculative behavior. We also examine the relationship between changes in profitability and changes in oil inventory over the pre-speculation and speculation period. Though some coefficients for inventory do switch from negative to positive over the two periods as hypothesized, they are only significant in a few cases. However, aggregate measures of inventory do switch and are significant, suggesting that, on average, inventory holdings negatively affected profitability in the pre-speculation period and positively affected profitability in the speculation period.

JEL Classification: D84; G12; G13; G18; M41; Q31; Q41

KEYWORDS: Speculation; Oil price; Oil market; Inventories; Accounting information; financialization

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1. Introduction

Oil prices matter. They influence macroeconomic performance and in turn they impact company profitability and financial markets (see, for instance Hamilton 1996; Hamilton 1983; Narayan and Narayan 2014; Narayan and Sharma 2011). Unsurprisingly, therefore, the oil spike of 2008 has generated intense academic and policy debate (see, for instance, Chan *et al.*, 2015 and Fattouth *et al.*, 2013). Specifically, researchers have sought to ascertain what role, if any, speculation[1] played in causing this spike. The majority of these studies have explored what impact financial institutions (non-commercial speculators) have had on price dynamics in the oil derivatives markets (principally oil futures). This can be broadly equated to the 'Masters hypothesis' following the interpretation, proposed by hedge fund manager Michael Masters before the US Congress and the US Commodity Futures Trading Commission, that commodity index investment was a major driver in causing the spike in commodity futures prices in 2008. This debate matters, since it not only helps explain the composition of prices consumers pay, but also leads to a debate about the regulation of energy markets and the need to control investor flows through positions limits (see, for instance, Diaz-Rainey *et al.*, 2011).

The resulting academic empirical studies have provided mixed and contradictory evidence. Fattouth *et al.* (2013) review the oil speculation literature, though this is not a comprehensive review nor does it fully reflect how mixed the evidence is. Irrespective of the approach taken by researchers, conflicting results exist. For instance, economic structural VAR modelling produced contrasting results are evident (see Kilian, 2009 contrasted with Lechthaler and Leinert, 2012). Similarly, when investment flows/trader positions and their

[1] The term 'speculation' is perhaps somewhat loaded, with some authors preferring to refer to 'precautionary demand'. Indeed, it is well recognized that speculation is necessary to have liquid markets. In this respect, the concern is with 'excessive speculation', which could be defined as speculation that is "beneficial from a private point of view, but would not be beneficial from a social planner's point of view" (Fattouth *et al.*, 2013; p. 9).

impact on asset correlations, price and risk premia are considered, a number of contributions find evidence against the speculative impact on price (Irwin and Sanders, 2012; Buyuksahin and Harris, 2011; Stoll and Whaley, 2010), while other studies find evidence in favor of the Masters hypothesis (Tang and Xiong, 2012; Singleton, 2014). Approaches that model volatility find mixed evidence also; for instance, Vivan and Wohar (2012) contrasts with Silvennoinen and Thorp (2010).

As noted above, most of the debate has centered on the role financial investors play in the oil futures market, thereby generally overlooking the possibility of speculation in the physical market by commercial traders. Fattouth *et al.* (2013, p. 9) note, however, that "[s]peculative buying may involve buying crude oil for physical storage leading to an accumulation of oil inventories, or it may involve buying an oil futures contract, provided an oil futures market exists." Further, there is anecdotal evidence that big oil companies and commodity traders do 'speculate' in physical markets. The hedged oil-storage trade, also known as (Contango and Carry Trade) becomes attractive for those with storage space when future oil prices are higher than the current spot price plus holding and hedging costs.[2] However, holding costs such as interest and storage costs are heterogeneous for different market participants. The rise of oil-storage trade is associated most with 2009.[3] The possibility remains, however, that with a clear momentum in oil prices between 2004 and 2008 some commercial traders might have built up inventories as either hedged (contango and carry trade) or unhedged speculative positions.[4]

[2] Strictly speaking the contango and carry trade is not speculation if one understands 'speculation' to entail some form of risk. It is, if well executed, a riskless trade.

[3] See "The Daily Mail discovers contango" (FTAlphavill 2009, http://ftalphaville.ft.com/2009/11/19/84321/the-daily-mail-discovers-contango/), "The Crazy Way Oil Traders Plan to Make Millions on Oil Prices" (The Motley Fool, 2015, http://www.fool.com/investing/general/2015/01/11/crazy-way-oil-traders-plan-to-make-millions-on-oil.aspx) and "Oil tanker demand booms as traders wait out cheap oil" (CBC, 2015 http://www.cbc.ca/news/business/oil-tanker-demand-booms-as-traders-wait-out-cheap-oil-1.2900556)

[4] Chan *et al.* (2015) attribute the contango of the oil markets in the second half of the 2000's to financialization. Thus the financialization may have supported speculation in the physical market by encouraging the contango and carry trade. This is suggestive of a bi-directionality in price formation between spot and futures (evidence of

Past research has explored the relationship between physical inventories and oil prices (Hamilton, 2009; Kaufmann, 2011; Kilian and Murphy, 2013; Singleton, 2014; Ye *et al.*, 2005; Ye *et al.*, 2006); however, these efforts have relied on two aggregate data sources (OECD inventories from the IEA and US inventories from the EIA). By way of contrast, this paper uses an alternative data source, namely the companies' own financial accounts, and asks the following research question: Can we infer from accounting inventory numbers whether companies involved in the physical oil market have been speculating in the run-up to 2008? Our contributions relative to the existing work using inventories are twofold: (1) we use an alternative data source that is more global and covers 'oil at sea' (unlike IEA and EIA datasets), and (2) we explore individual company data and, therefore, can explore the heterogeneity of company behavior. The former is important, since both the IEA and EIA datasets do not capture emerging markets and do not cover 'oil at sea', which is critical since physical speculation in oil usually involves holding positions in oil tankers. The latter is also important because past research on inventories has not been able to explore individual company behaviors, and thus our results challenge anecdotal and research-based conclusions drawn from aggregate data that suggested either all companies or none were involved in speculation. The reality is more nuanced; the evidence we find is consistent with some companies speculating and others not.

More specifically, using quarterly inventory data over the period 1990Q4 to 2012Q1 and an initial sample of 15 of the largest listed oil companies in the world, we derive an Index of Scaled Physical Inventories (ISPI). ISPI takes account of exchange rate differences, the price of oil and the size of the company (as measured by sales). We employ three methods to explore the research question. Method 1 is a descriptive evolution of ISPI over time, while method 2 uses the Bai-Perron multiple structural breaks test on individual company time

which is provided by Kaufmann and Ullman, 2009) which could lead to re-enforcing speculative price pressures (on the upside as well as the downside).

series and on ISPI time series (positive structural breaks during the speculation period would be suggestive of speculative activity). Method 3 employs a predictive model of operating profit using the number of barrels of oil, measured as inventory divided by the crude oil price per barrel, as an explanatory variable for the pre-speculation period (1990Q4 to 2004Q3) and the speculation period (2004Q4 to 2008Q2), with the latter defined by structural breaks in the oil price. We hypothesize that in the pre-speculation period inventory is a drag on performance (expect a negative coefficient), while during the speculation period we expect inventory to switch to be positively associated with performance.

The rest of the paper is structured as follows: Section 2 explores the theoretical and empirical work on inventory and oil prices; Section 3 describes the data used; Section 4 outlines our empirical approach, including the econometric models employed; Section 5 presents the results; and in Section 6 we provide some concluding remarks.

2. Theory and Evidence on the Inventory and Oil Price Relationship

2.1. Theoretical Relationship

We hypothesize a state dependent relationship between inventory, oil prices and, in turn, the operating profitability of commercial traders. Intuitively, if oil prices are rising and are expected to continue to rise ($E(P_{t+n}) > P_t$), momentum trades holding physical inventory will be profitable, so long as capital gains are greater than the cost of carry (s), hence $(E(P_{t+n}) - P_t) - s > 0$. This trade is, however, risky since prices may not in fact rise. Alternatively, traders can make a riskless profit through the contango and carry trade. Expectation of rising prices are likely reflected in a futures contango market, whereby futures prices are higher than spot prices (i.e. $F_{t,T} > P_t$). Traders can buy spot oil and sell it into the future instantly and make a riskless profit, so long as the capital gain is greater than the cost of carry, that is, $(F_{t,T} - P_t) - s > 0$. Indeed, as is discussed below, Singleton (2014) finds evidence of inventory and price relationship switching from negative to positive in 2004 when the oil market had considerable momentum and just before the oil market entered into contango in 2005.

A number of researchers have developed models that support the above intuition, namely that there are strong incentives to hold inventory when prices are rising (see related discussion in Dvir and Rogoff, 2010; Hamilton, 2009; and Singleton, 2014). It would follow that when the opposite is the case (there is no clear upward momentum on price), inventory is likely to be a drag on performance, and so companies would seek to minimize holdings all other things being equal. This noted, there are 'convenience' reasons for holding oil that may lead to a positive relationship between company profitability and inventories when the price of oil is not in a momentum phase.

From the discussion above, we develop our hypothesis by outlining two simple states:

State 1: Non-Positive Momentum Market. Oil prices are declining or flat and are not expected to rise. In this context, there is little incentive to hold physical oil for speculative purposes (though there may be a convenience motivation for holding it); accordingly, we develop our first hypotheses:

H1*: As physical oil inventories are a drag on performance, all commercial traders will seek to minimise inventory holdings; accordingly, we expect ISPI to decline as oil companies squeeze greater efficiencies out of their supply chains.*

H2*: Following from the above, those companies with high inventories will suffer in terms of profitability and vice versa; thus there will be a negative relationship between inventories and oil company profitability.*

State 2: Positive Momentum Market (supported by contango), Oil prices are rising and are expected to continue to rise (signalled by a contango market, i.e. $F_{t,T} > P_t$). In this context, unhedged momentum and potentially hedged contango and carry trade become profitable. However, not all physical market participants are willing to speculate; some may not do so due to (irrational) risk aversion, reputational risk and institutional characteristics. In the latter case, for instance, Exxon explicitly states in its accounts that it seeks to hedge all market risk and ‘does not speculate’. This leads to our next hypotheses:

H3: *During positive momentum markets, the heterogeneity of inventory behaviours will be apparent. Accordingly, some oil companies will speculate, as evidenced by positive structural breaks in inventory, while others do not, as evidenced by no or negative structural breaks.*

H4: *During positive momentum markets, the relationship between inventory and profitability switches relative to Hypothesis 2, that is, becomes positive rather than negative. The relationship will be stronger for oil companies that have experienced a positive structural break in inventory since the commencement of the momentum market.*

2.2. Empirical Evidence

> *“The IMF has rightly argued that if momentum trading ….was driving prices, one would have seen rising inventories of oil, which is a storable commodity. Since oil inventories have not risen, this would reject the possibility of momentum trading. But in the case of oil, one should not draw strong inferences because the data on oil inventories are notoriously poor, with many countries not reporting at all. In particular, most non-OECD countries, which make up a little less than half of world demand for crude oil and include very large consumers such as China, do not report data on oil inventories. Furthermore, oil inventories do not include oil in tankers, commonly referred to as “oil at sea,” which distorts even the inventories data reported by the United States and other OECD countries.”* (Khan 2009, p5)

The quote above highlights some of the data challenge of exploring the relationship between oil inventories and oil prices. Attempts to do so predating the 2008 spike include Ye *et al.* (2005) and Ye *et al.* (2006), both of which use IEA data for the OECD. Building on Ye *et al.* (2005), the same authors in Ye *et al.* (2006) find that a nonlinear model that captures very high and very low inventory levels improves forecast accuracy over a model that assumes a linear relationship between inventories and oil prices. Generally, this work is positive about the ability to use inventory to predict oil prices, but the authors utilize purely statistical models as distinct to models with underlying theoretical *a priori* expectations. As such, the models are effective at forecasting but do not shed much light on the fundamental relationship between inventories and price.

More recently, a number of papers have explored crude inventories following the 2008 spike (Hamilton, 2009; Kaufmann, 2011; Kilian and Murphy, 2013; Singleton, 2014). As in the case of the literature exploring the impact of financial speculators (see Section 1), the evidence with respect to the impact of inventories on price is also mixed.

Building on Kilian (2009), Kilian and Murphy (2013) use a structural VAR model that utilizes EIA inventory data scaled to approximate global inventory balances, which are in turn seen as a proxy for the speculative component in oil prices. Consistent with Kilian (2009), the results of Kilian and Murphy (2013) suggest that speculative demand has played a role in past oil shocks but not in the 2008 price spike. By incorporating inventory balances, Kilian and Murphy (2013) overcome one of the criticisms of Kilian (2009) that it did not formally model the speculative component, as this was captured by the residuals (see Lechthaler and Leinert, 2012). However, neither Kilian (2009) or Kilian and Murphy (2013) account for structural breaks (Lechthaler and Leinert, 2012). Our own evidence (see Section 5 and Figure 3) and that of Lechthaler and Leinert (2012) suggest structural changes in oil prices around 2003/2004,[5] which is important with respect to our hypothesized switch in inventory behaviour during momentum markets (see Hypothesis 4, above). Indeed, and as intimated in the development of Hypothesis 4, Singleton (2014) finds that the relationship between inventory and oil prices switches from negative to positive in 2004 and that non-strategic (i.e. private) US inventories increase when the oil market is in contango.

In a simply descriptive analysis, Hamilton (2009) compares EIA inventories in 2007 and part of 2008 with a long-run average, finding that though inventory levels in the first half of 2007 were higher than long-run averages, they subsequently declined and stayed below average in the first half of 2008. However, the long-run average includes periods of potential speculation activity in 1990 (see Kilian and Murphy, 2013) and 2004 to 2007 that may have potentially biased their analysis (see Kaufmann, 2011). Indeed, Kaufmann (2011) finds that an examination of US private inventories over time show a decline from 1984 through to 2004, after which they start to increase. This is suggestive of speculation starting in 2004, though as the author concedes, in this debate finding a 'smoking gun' is virtually impossible.

As noted earlier, all of the above empirical literature relies on two aggregate data sources (OECD inventories from the IEA and US inventories from the EIA). As Khan (2009) observes, these datasets are limited in that they do not cover 'oil at sea' (important since many physical trading positions are likely to be held in tankers)[6] and exclude inventories held outside the OECD countries. To overcome both these issues, we use oil inventory data from company accounts that are global, since the companies covered in the sample tend to have global operations, and will cover all inventories including 'oil at sea'.

[5] These breaks coincide with the observation that financialization of the oil markets commenced around this period (see Chan *et al.*, 2015; Diaz-Rainey *et al.*, 2011; Tang and Xiong, 2012).
[6] Kilian and Murphy (2013, p. 460) dismiss the importance of 'oil at sea' but do not substantiate this.

3. Data

The data used in the study are sourced from the Compustat. The quarterly data for the 15 largest publicly traded oil companies, based on the SIC code 1311, are gathered to build an initial sample for the period 1990Q4 to 2012Q1. The firms included are British Petroleum, Royal Dutch Shell, Statoil, Total, Chevron, Conoco Phillips, Exxon Mobil, Valero Energy, ENI, Gazprom, Lukoil, Petrobras Brasileiro, China Petroleum and Chemicals, Sasol and Repsol. The variables used for the study are earnings before interest, tax, depreciation and amortization (EBITDA); inventory (INV); days to sales; sales; cash; current assets and current liabilities; long-term debt (LTD); total shareholders' equity; property, plant and equipment (PPE); total assets (TA) and the quarterly mean Brent crude oil price. These are defined in Table 1 together with their mnemonic.

Summary statistics for the data across the 15 oil companies and the ISPI measures based upon the five (ISPI_5) and six (ISPI_6) firms with the most observations, respectively, are reported in Table 2.[7] In terms of total assets, the firms range in size from the largest, Gazprom with assets of US$377,729 million per quarter reported down to US$1,254 million for Valero. Total asset standard deviation varies from US$6,932 million reported by Sasol to US$98,099 million for Petrobras during the sample period. Sales levels also demonstrate considerable heterogeneity across the sample. Exxon Mobil reported average sales of US$55,161 million per quarter, whereas Sasol has average sales of only US$2,493 million per quarter. The level of sales generated by individual firms within the sample also varies considerably. For example, Royal Dutch reports a maximum (minimum) quarterly sales figure of US$131,567 (US$20,771) million. In comparison, Repsol has a maximum (minimum) reported sales of US$26,483 (US$3,293) million. The EBITDA figures show similar variation. Exxon has the largest EBITDA at more than US$24,367 million per quarter.

[7] The five-firm measure uses data for British Petroleum, Royal Dutch Shell, Chevron, Conoco Phillips and Exxon Mobil. The six-firm measure also includes Total SA.

Table 1: Variable Definitions

This table reports the variables used in this study together with their Research Insight mnemonic and corresponding definitions as well as measures calculated from the data sourced from Compustat.

Variable	Name	Mnemonic	Definition
EBITDA	Quarterly earnings before interest and tax	EBITDAQ	Quarterly operating income before amortization and depreciation.
INV	Quarterly inventories	INVTQ	Quarterly crude oil supplies used for the production of revenue.
Days to Sales	Quarterly days to sales	SELLINVQ	The average of the most recent four quarters of inventories divided by the sum of the cost of goods sold (using a 12 month moving average) divided by 360.
Sales	Quarterly net sales	SALEQ	Net sales for any revenue source that is expected to continue for the life of the company.
Cash	Quarterly cash and equivalents	CHEQ	Cash and equivalents reported as part of current assets.
CA	Quarterly current assets	ACTQ	Cash and other assets that are expected to be realized in cash in the next 12 months.
CL	Quarterly current liabilities	LCTQ	Quarterly liabilities due within one year including short-term debt and the current portion of long-term debt.
LTD	Quarterly long-term debt	DLTTQ	Long-term debt is debt obligations held by the firm due more than one year from the firm's balance sheet date.
SE	Quarterly total stockholders' equity	SEQQ	Common and preferred shareholders interest in the company.
PPE	Property, plant and equipment	PPENTQ	Quarterly net tangible fixed property used in the production of revenue.
TA	Quarterly total assets	ATQ	Quarterly current assets plus net property, plant and equipment plus other noncurrent assets.
Oil Price	Brent crude oil price per barrel		Quarterly average calculated from the daily Brent crude oil price reported by Bloomberg.
LEV	Leverage		Calculated as the ratio of LTD/SE
LIQ	Quick Ratio		Calculated as (CA – INV)/CL
Q	Quantity of barrels of crude oil		Calculated as INV/Brent crude oil price per barrel.

Table 2: Summary Statistics

This table reports the mean, maximum, minimum and standard deviation of the number of barrels of crude oil (Q), Inventory/Sales ratio, the Days to Sales, total assets (TA,) the quarterly sales, the quarterly cash and cash equivalents reported in current assets, liquidity (LIQ) measured using the quick ratio, leverage measured as the ratio of long-term debt to total shareholder equity (LEV), EBITDA, and property, plant and equipment (PPE). AVG_5 measures the summary statistics using the data for the five firms with the longest times series available (British Petroleum, Royal Dutch, Chevron, Conoco and Exxon). AVG_6 is AVG_5 and also includes Total SA. The last line of the table shows the equivalent summary statistics for the price of a barrel of crude oil. The quarterly data summary statistics are based on disclosures for the period 1990Q4 to 2012Q1.

Panel A	Sample	Number of Barrels (m)				Inventory/Sales				Days to Sales				Total Assets (U$m)				Sales (U$m)			
	Size	Mean	Max	Min	Stdev	Mean	Max	Min	Stdev	Mean	Max	Min	Stdev	Mean	Max	Min	Stdev	Mean	Max	Min	Stdev
British Petroleum (BP)	85	289	410	165	55	0.27	0.44	0.09	0.07	30	40	18	7	142,955	303,544	45,828	83,884	44,045	108,747	11,532	28,180
Royal Dutch Shell (RD)	84	389	610	266	71	0.28	0.39	0.20	0.04	33	44	25	5	177,063	359,300	97,909	82,871	53,261	131,567	20,771	31,982
Statoil (STAT)	53	33	57	14	11	0.12	0.19	0.04	0.04	17	28	8	7	58,108	136,577	18,746	36,723	15,009	34,141	3,270	9,213
Total SA (TOT)	62	228	380	104	58	0.30	0.44	0.08	0.10	38	50	22	9	113,501	223,535	18,353	61,813	33,977	68,141	4,967	15,133
Chevron (CHEV)	86	89	165	32	30	0.15	0.30	0.03	0.06	17	32	6	8	84,472	214,890	33,729	57,331	27,263	78,310	3,934	20,673
Conoco Phillips (CP)	86	63	154	13	39	0.18	0.49	0.06	0.08	19	37	11	6	69,956	190,155	10,943	65,419	18,300	69,217	2,539	18,369
Exxon Mobil (EX)	86	276	887	118	105	0.18	0.25	0.11	0.04	20	27	15	4	161,999	345,152	81,744	75,456	55,161	124,238	22,883	29,063
Valero Energy (VAL)	86	37	111	6	27	0.26	0.95	0.11	0.13	27	75	12	16	16,273	43,807	1,254	15,994	10,102	36,436	195	10,986
Eni Spa (ENI)	51	140	385	70	85	0.27	0.43	0.15	0.06	30	33	27	2	95,192	193,591	26,953	52,225	20,964	45,086	7,866	11,064
Gazprom (GAZ)	41	116	226	77	28	0.41	0.72	0.20	0.12	55	68	43	7	203,279	377,729	73,139	94,914	19,303	46,323	4,241	12,205
Lukoil (LUK)	55	48	90	9	19	0.22	0.32	0.09	0.05	32	39	28	2	43,758	95,749	4,208	28,426	12,617	35,261	1,007	11,118
Petrobras (PET)	55	131	279	89	32	0.48	0.78	0.28	0.10	64	78	52	9	108,447	354,911	24,707	98,099	15,269	39,042	2,738	11,040
China Petr (CH)	35	242	338	174	49	0.41	0.66	0.29	0.10					89,466	191,951	42,844	45,268	37,386	106,549	7,974	28,744
Sasol (SAS)	55	27	62	10	9	0.49	0.71	0.12	0.15					11,022	26,248	2,715	6,932	2,493	5,562	784	1,498
Repsol (REP)	35	84	126	61	14	0.38	0.87	0.07	0.20	39	46	33	4	47,240	97,029	10,633	26,073	11,209	26,483	3,293	6,519
Average_5	86	209	296	113	32	0.21	0.31	0.13	0.04	24	33	17	4	126,504	277,153	45,380	71,844	39,606	102,386	13,546	24,713
Average_6	86	221	382	157	37	0.23	0.42	0.14	0.05	25	33	17	4	122,091	268,217	45,380	69,354	37,935	96,679	13,133	23,024
Panel B		Cash (U$m)				Liquidity				Leverage				EBITDA (U$m)				PPE (U$m)			
British Petroleum (BP)	85	3,459	20,165	259	4,827	0.75	0.99	0.64	0.07	0.30	0.77	0.11	0.19	7,038	15,569	-23,540	5,293	68,478	119,991	29,310	31,251
Royal Dutch Shell (RD)	84	9,500	19,465	1,556	4,261	0.88	1.17	0.53	0.15	0.12	0.26	0.03	0.05	7,665	20,745	1,930	4,132	82,581	155,239	46,801	28,868
Statoil (STAT)	53	4,613	16,332	138	4,093	0.90	1.13	0.61	0.12	0.50	1.11	0.20	0.25	5,077	15,218	392	3,891	33,204	71,695	11,481	19,330
Total SA (TOT)	64	11,889	28,392	2,396	7,549	1.02	1.32	0.83	0.10	0.35	0.47	0.29	0.05	6,403	16,993	485	3,915	44,258	86,759	6,423	22,940
Chevron (CHEV)	86	5,978	20,335	1,250	5,369	0.93	1.49	0.60	0.27	0.24	0.45	0.07	0.10	4,706	14,187	71	3,909	47,527	124,798	21,458	31,081
Conoco Phillips (CP)	86	1,243	11,510	67	2,254	0.75	1.11	0.38	0.15	0.75	1.63	0.20	0.41	3,339	12,279	136	3,451	38,439	89,990	7,852	32,967
Exxon Mobil (EX)	86	11,299	41,393	1,088	11,250	0.84	1.38	0.50	0.26	0.13	0.26	0.05	0.07	8,788	24,367	2,528	5,806	98,592	214,664	60,324	41,130
Valero Energy (VAL)	86	689	4,133	0	1,000	0.80	2.09	0.51	0.25	0.60	1.18	0.25	0.23	587	3,534	-105	779	9,313	25,177	806	9,091
Eni Spa (ENI)	51	3,998	13,436	1,964	2,212	0.82	1.21	0.37	0.16	0.29	0.73	0.16	0.11	5,677	13,598	1,557	2,961	52,736	97,513	22,159	27,538
Gazprom (GAZ)	41	11,888	38,520	1,423	8,488	1.39	1.96	0.84	0.26	0.19	0.28	0.13	0.03	7,832	20,626	1,386	5,188	118,562	231,854	54,068	49,526
Lukoil (LUK)	55	1,792	4,591	237	1,036	1.31	1.69	0.88	0.16	0.14	0.25	0.09	0.03	2,662	6,436	-141	1,656	27,673	58,079	1,849	18,571
Petrobras (PET)	55	10,371	38,979	193	9,668	0.99	1.59	0.24	0.31	0.45	1.39	0.18	0.20	4,588	11,936	423	3,213	60,929	195,140	8,689	58,006
China Petr. (CH)	35	2,508	5,011	985	1,173	0.39	0.82	0.19	0.15	0.40	0.48	0.29	0.04	3,510	7,778	872	1,899	60,686	107,430	25,424	27,676
Sasol (SAS)	55	730	3,095	66	769	1.19	1.97	0.61	0.35	0.18	0.51	0.02	0.10	718	1,617	-916	474	6,705	16,123	1,818	4,155
Repsol (REP)		3,242	9,617	124	2,196	0.97	1.50	0.47	0.23	0.54	1.93	0.06	0.28	1,957	4,579	-214	1,048	28,311	48,209	4,971	12,457
Average_5	86	6,261	15,154	1,255	4,363	0.83	1.02	0.67	0.10	0.31	0.61	0.11	0.14	6,001	16,386	1,598	3,971	66,823	140,038	30,758	31,540
Average_6	86	6,839	17,219	1,255	4,764	0.85	1.01	0.69	0.09	0.32	0.61	0.14	0.13	5,903	16,487	1,598	3,921	62,807	131,158	30,758	29,250
Oil Price per barrel	86	41.36	133.05	9.80	31.49																

In contrast, Sasol reports maximum EBITDA of only US$1,617 million per quarter. The summary statistics also show that the firms experience considerable operating losses during the period. Most notable is British Petroleum's US$23,540 million quarterly loss. Exxon reports a minimum quarterly EBITDA of US$2,528 million during the period but also has the highest average EBITDA, at US$8,788 million per quarter.

The inventory/sales ratio can be used to gauge how efficiently inventory is managed. It is the reciprocal of the inventory turnover ratio. Hence, a low inventory/sales ratio is consistent with an adequate inventory management program. From Table 2, the mean inventory/sales measure ranges from a minimum of 0.12 for Statoil to a maximum of 0.49 for Sasol. The inventory/sales measure ranges from a minimum of 0.03 to a maximum of 0.95 for Chevron and Valero, respectively. The wide variation in this scaled inventory measure is clear from the reported standard deviation that ranges from 0.04, for Royal Dutch, Statoil and Exxon, to 0.20 for Repsol. The low standard deviation in scaled inventory for Exxon Mobil is consistent with the firm's disclosed policy of not holding positions for speculative gain. Inventory management figures measured by days to sales also demonstrate considerable variation across the different oil companies. Mean days to sales range from a high of 64 for Petrobras Brasileiro to 17 for Chevron and Statoil. Petrobras also has the maximum level of days to sales reported over the sample period at 78 compared with Chevron, which reports a minimum of 6. The standard deviation in days to sales confirms the amount of volatility in days to sales across the 15 firms. Eni Spa and Lukoil both report a standard deviation of only 2 compared with Valero Energy's 16 per quarter. Physical quarterly holdings of barrels of crude oil show that Royal Dutch held 389 million barrels on average compared with a minimum of only 27 million held by Sasol.

The heterogeneity in the sample is also apparent from the summary statistics for the control measures. Average cash and cash equivalent holdings vary from $689 million for

Valero to \$11,889 million for Total. During the period of our study firms experience a range of very high and very low cash holdings in their current assets. Valero reported cash of only U\$0.01m in Q4 of 1996 (reported as a minimum of zero in Table 1). In a similar vein, the firms demonstrate very high and extremely low levels of liquidity (measured using the quick ratio).[8] China Petroleum reports a minimum liquidity measure of 0.19 compared with Valero's high of 2.09. Average leverage, measured as long-term debt divided by total shareholders' equity, is typically below 50% during the period of study; however, firms do hold very high and very low levels of long-term debt to total shareholder equity. In particular, Repsol reports a high leverage ratio of 1.93 compared with only 0.02, the minimum in the sample disclosed by Sasol. Property, plant and equipment measures the investment in tangible assets across our sample. Gazprom has the highest dollar investment in PPE for the period with a maximum value of \$231,854 million invested in physical assets. This compares with Valero, who held a minimum investment in PPE of \$806 million.

The summary statistics confirm the heterogeneity in the firms sampled across the various control, inventory and performance measures reported. Overall, the summary statistics reported in Table 2 highlight the heterogeneity in the scaled inventory, days to sales, sales and operating profitability of the firms in our sample. Exploring the individual company data further will allow us to examine the heterogeneity of company behavior regarding inventory holdings and oil price speculation.

4. Methodology

4.1. ISPI (Index of Scaled Physical Inventories)

Using quarterly inventory data over the period 1990Q4 to 2012Q1, we derive the ISPI. Our company level measure of scaled inventory is

[8] The quick ratio = $\frac{(Current\ Assets - Inventory)}{Current\ Liabilities}$.

$$V_{i,t}^{S} = \left(I_{i,t}/S_{i,t}\right), \tag{1}$$

where *I* refers to the dollar reported inventory of company *i* at the quarterly time period *t* and *S* is the equivalent measure for sales. The ISPI is given by

$$\frac{1}{n}\sum_{j=1}^{n} V_{j.t}^{S} = \bar{V}_{t}^{IS} \tag{2}$$

for each quarter in the sample. ISPI takes account of exchange rate differences, since all the data are measured in US Dollars (US$); it also accounts for the price of oil, since both the numerator and denominator are impacted by oil prices and the size of the company (as measured by sales). The ISPI measures the average level of scaled physical inventories based on each of the *n* oil companies included in the average value, as shown in equation (2).

The first method that we use to explore the research question is a descriptive evolution of the ISPI over time together with an examination of the ISPI $\pm$ 1 standard deviation of ISPI to explore the heterogeneity of behavior in ISPI over time. As a second measure of oil company inventory holdings, we also examine days to sales.[9] This measure is already calibrated to account for firm size by sales. We calculate the ISPI for days to sales as

$$\frac{1}{n}\sum_{k=1}^{n} Days\ to\ Sales_{k} = \bar{V}_{t}^{DS}. \tag{3}$$

4.2. Structural Breakpoint Tests

The second method applies the Bai-Perron (1998) multiple structural breaks test using the Global Information Criterion to each of the individual company time series for inventory scaled by sales and days to sales, as well as to the time series of crude oil prices. The structural breaks test is also used on the ISPI time series, calculated on the five (ISPI_5) and six (ISPI_6) firms, respectively, with the most observations in the sample. We then compare

[9] Days to sell inventory is calculated using the average of the most recent four quarters of inventories divided by the sum of the 12-month moving cost of goods sold divided by 360.

the oil price break points with the company break points to identify periods where inventory holdings suggest speculative behavior in the run-up of oil prices prior to 2008.

4.3. Profit Model Using Inventory as an Explanatory Variable

The third method used to explore the research question examines the empirical relationship between changes in operating profit, changes in inventory, changes in oil price per barrel and changes in firm size (as measured in sales). We use standard control variables when undertaking this, including leverage (discussed further below). This relationship is modelled during the pre-speculation period (1990Q4 to 2004Q2) and the speculation period (2004Q3 to 2008Q2).[10] The model employed is

$$\Delta EBITDA_{i,t} = \alpha_1 + \alpha_2 \Delta Q_{i,t-1} + \alpha_3 \Delta P_t + \alpha_4 \Delta Cash_{i,t} + \alpha_5 \Delta LIQ_{i,t} + \alpha_6 \Delta LEV_{i,t} + \alpha_7 \Delta Sales_{i,t} + \alpha_8 \Delta PPE_{i,t} + \varepsilon_{i,t} \quad (4)$$

where EBITDA measures the operating earnings before amortization and depreciation; Q_{t-1} is the number of barrels of oil held in the prior quarter; P is the price of crude oil per barrel; Cash measures the level of cash and cash equivalents; LIQ is liquidity measured by the quick ratio; LEV measures the ratio of long-term debt to total shareholders' equity; S is sales and $PPE_{i,t}$ is the level of property, plant and equipment held by firm *i* in quarter *t*. We are particularly interested in the sign and significance of α_2, the coefficient on the change in the actual number of barrels of oil held by the firm. Our expectation is that the sensitivity of changes in firm operating profit to changes in oil inventory holdings will be negative in a non-positive momentum market (see Hypothesis 2, Section 2.1) and positive in a momentum and contango market (Hypothesis 4). Hence, we generally expect the coefficient to be negative in the pre-speculation period and positive during the speculation period.

[10] See Section 5.2 for an explanation of how we define the 'speculation' period.

5. Results

5.1. Descriptive Results

The ISPI measure $\pm$ 1 standard deviation using the inventory to sales measure together with the Brent crude oil price is shown in Figure 1a. The ISPI is calculated using the average scaled inventory measures for all 15 oil companies. We have annotated the graph to identify the first Gulf War, the economic slowdown following the dot.com bubble and the second Gulf War. Corresponding shifts in the oil price around these dates can be seen from the graph.

Consistent with Hypothesis 1, ISPI declines until the turn of the century and the declining standard deviation suggests a drive for efficiency shared by most industry participants (homogeneity in behavior). However, this changes as the Brent crude oil price starts to increase after Q3 in 2003 and continues to rise up to a maximum in Q2 of 2008. The one-standard-deviation band around the ISPI measure begins to widen at the turn of the century. The greater standard deviation supports heterogeneity in inventory behaviors among the companies included in the ISPI. This is consistent with Hypothesis 3, suggesting more variation in decisions concerning the amount of inventory being held by each firm as the market enters a momentum phase.

During the period prior to Q3 of 2003 when the oil price was declining or flat, there was no economic incentive for oil companies to hold physical oil for speculative purposes (Hypothesis 1). Conversely, oil companies anticipating a positive momentum market from 2003 onwards could take on profitable speculative inventory positions. The large standard deviation around the ISPI measure post Q3 of 2003 is consistent with a subset of firms (Hypothesis 3) holding greater oil inventory in anticipation of the rising crude oil price.

Figure 1a: Descriptive Results for ISPI ± 1 SD Measured by Inventory Scaled by Sales

The graph shows the ISPI measure ± 1 standard deviation for the 13 oil companies throughout the sample period. The left axis reports the ISPI measure and the right axis reports the price of a barrel of crude oil. The width of the band measuring the standard deviation either side of the ISPI measure widens after Q4 of 2000. The standard deviation around the mean Inventory/Sales measure remains high until Q1 of 2008.

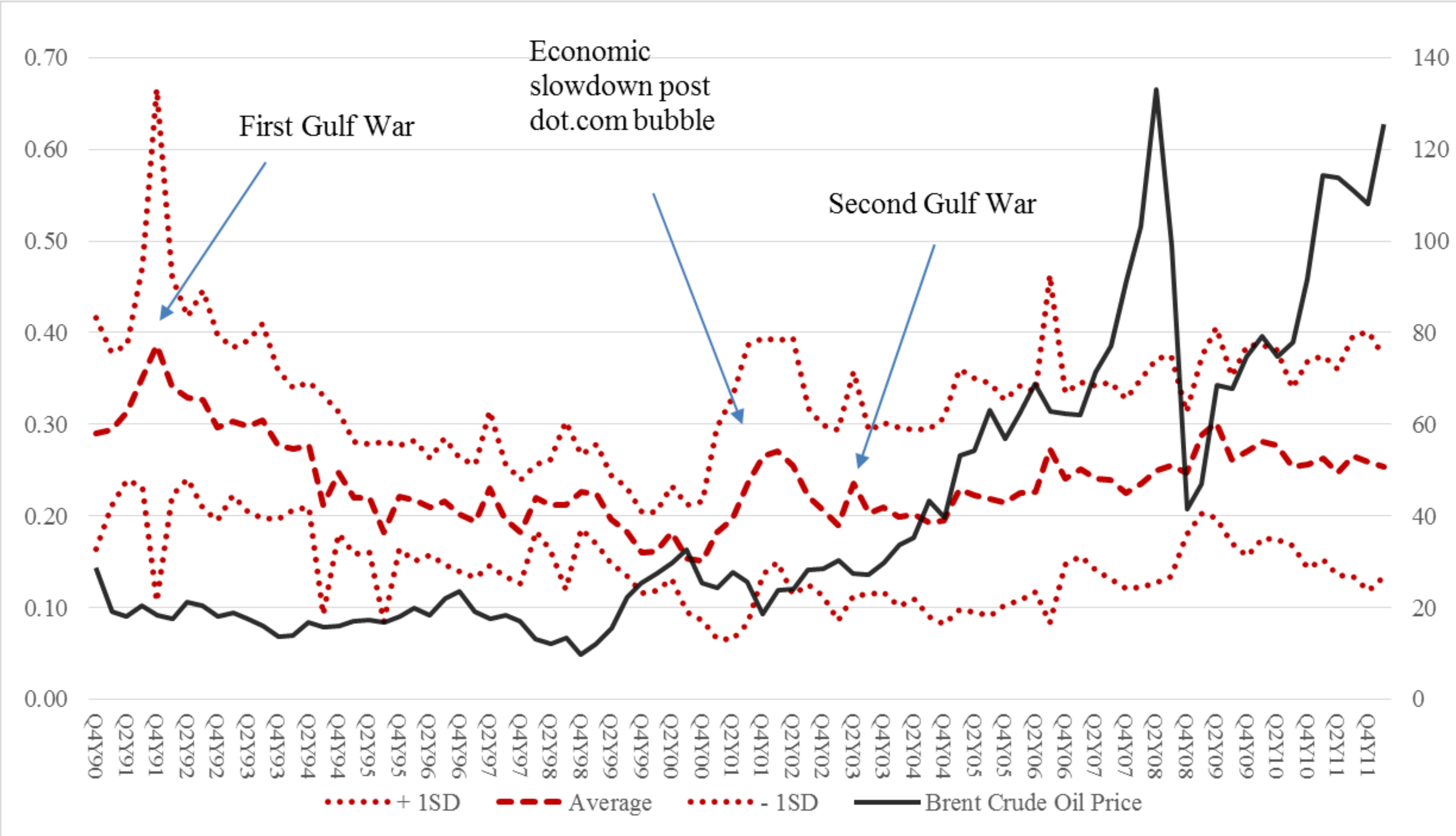


Figure 1b: Descriptive Results for ISPI ± 1 SD Measured by Inventory Scaled by Sales for the Five Companies with Continuous Data
Figure 1a shows data for all 13 companies in the sample but since data for most of these is incomplete it is possible that ISPI is biased by the entry into the index of a company. Accordingly, as a robustness exercise we calculate ISPI for the five companies with continuous inventory to sales data throughout the period of analysis (86 quarters, see Table 2). The trend is similar though there is less of an increase in ISPI post 2000.

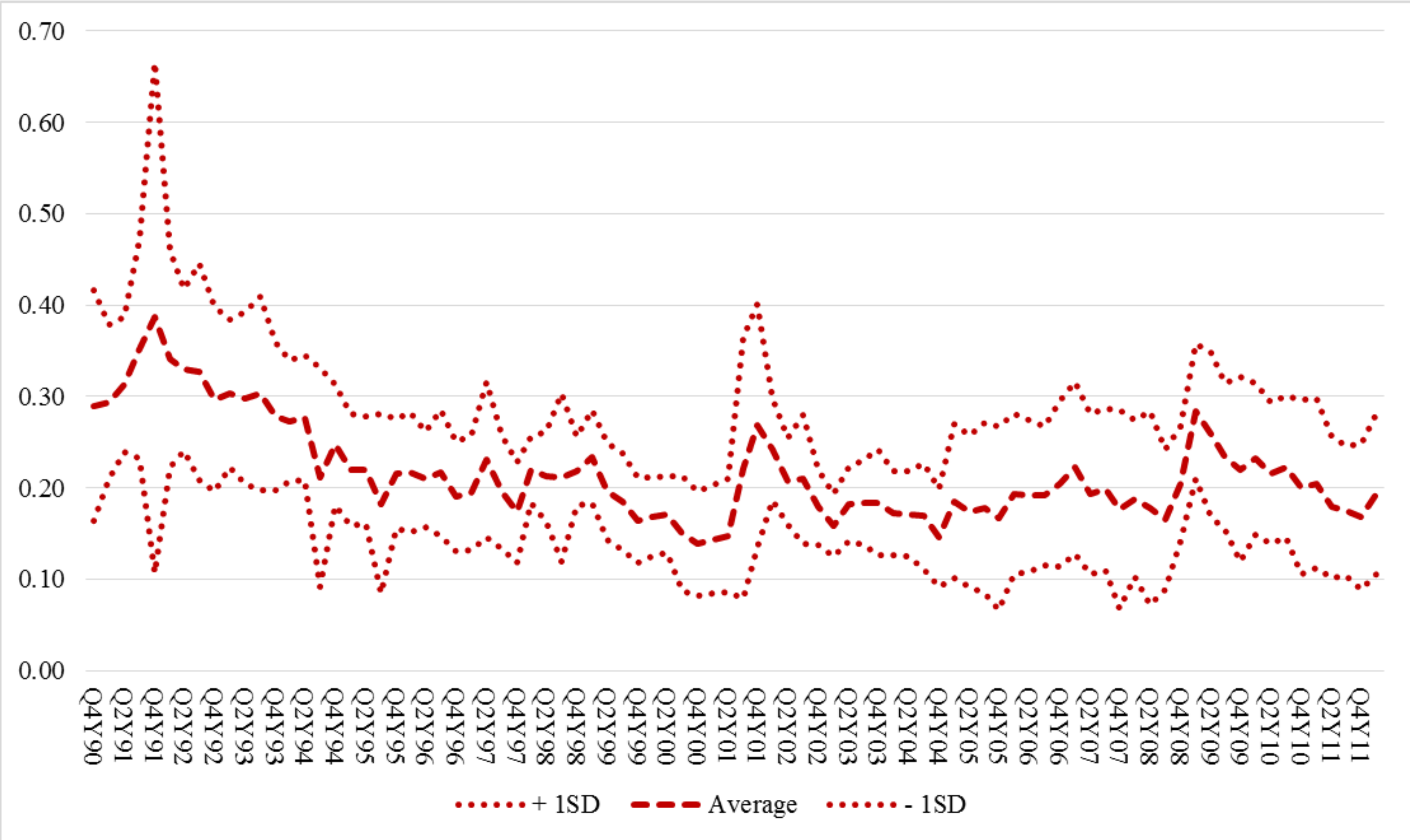


Figure 1c: Descriptive Results for ISPI ± 1 SD Measured by Days to Sales

This is the equivalent of Figure 1a for days to sales for 12 of the 13 companies (Petrobras was omitted as it was an outlier in terms of days to sales).

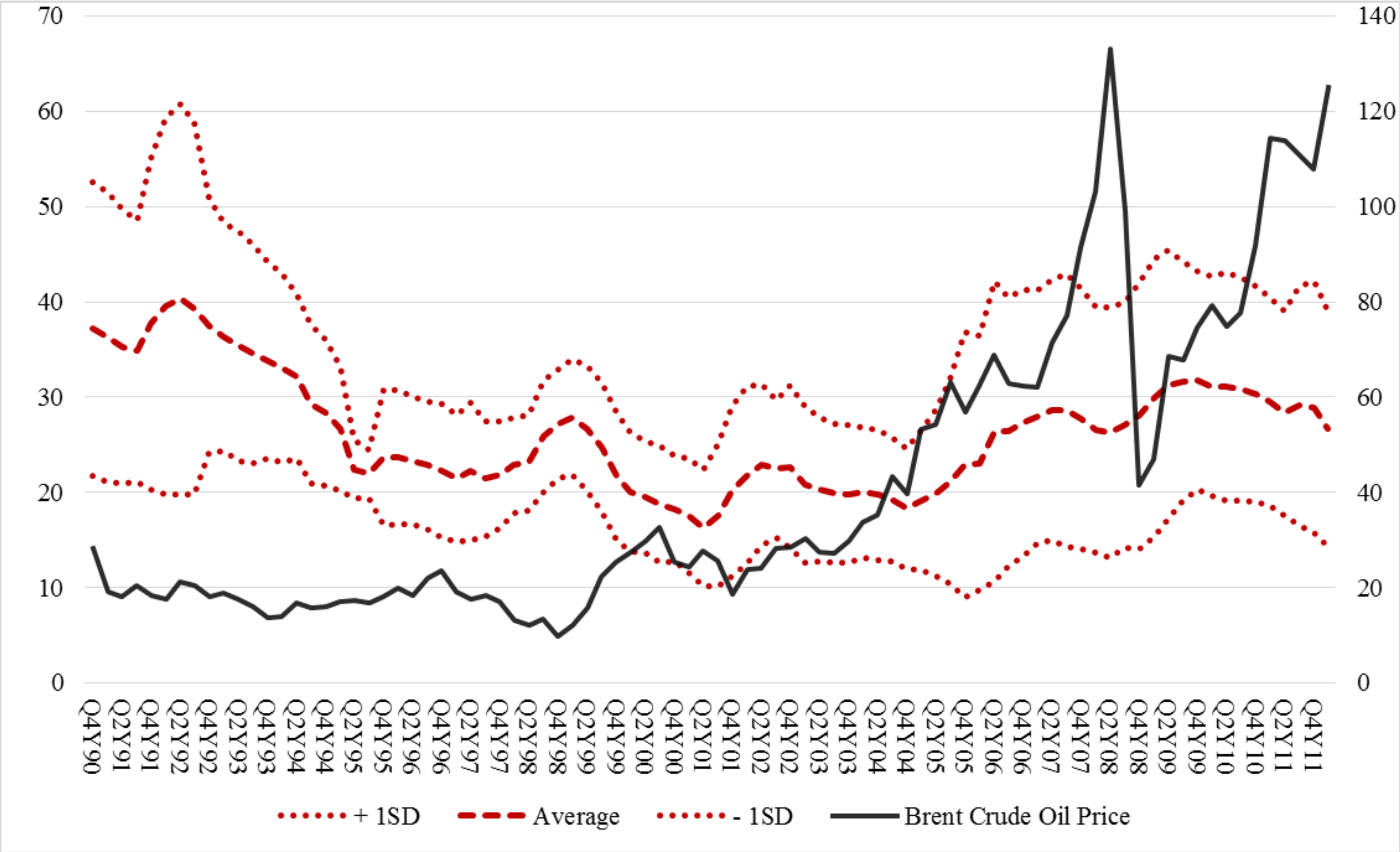
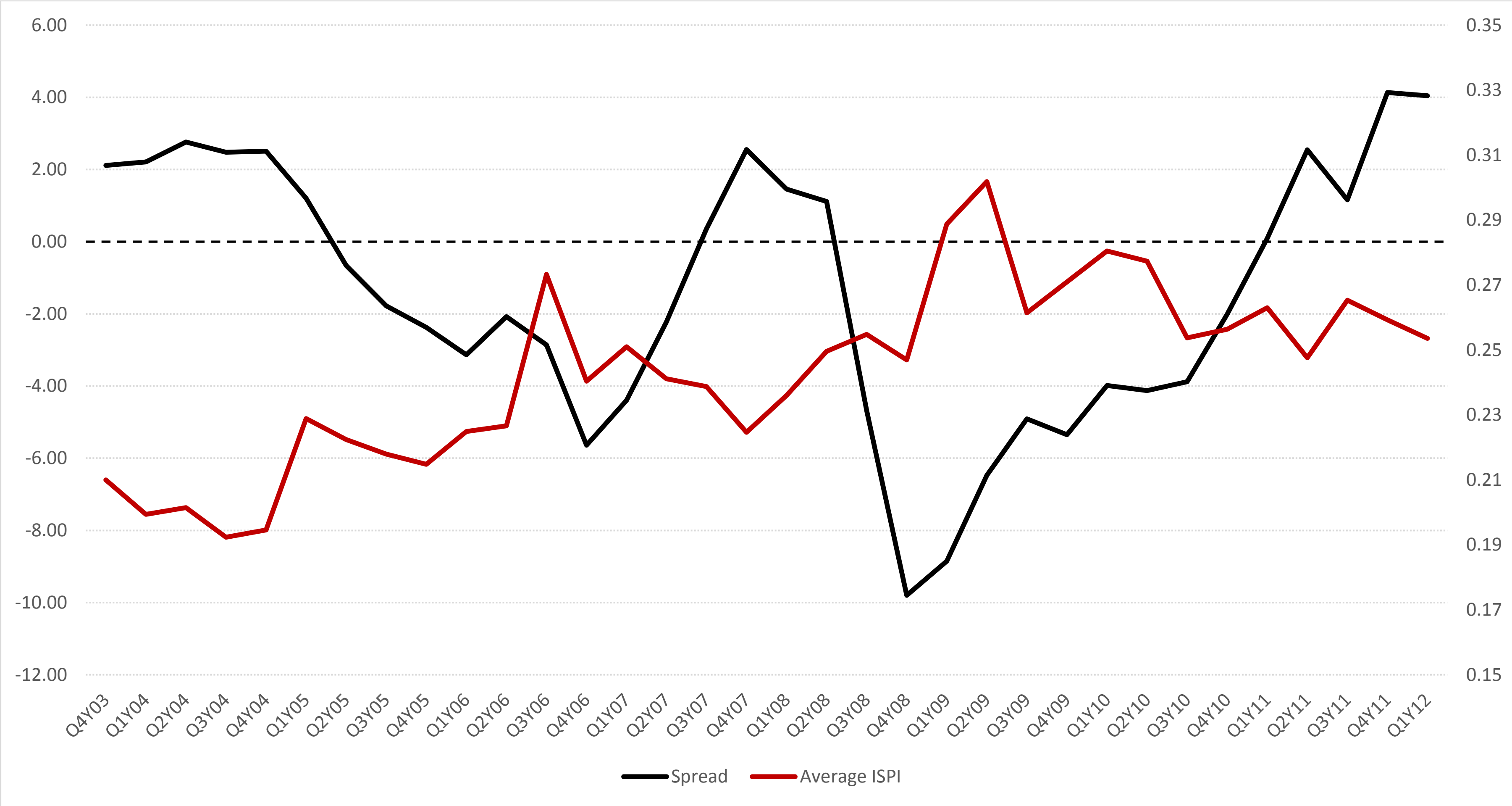


Figure 2 Futures Spread and ISPI around the speculation period

The figure charts the average quarterly spread between the ICE Brent Crude front month futures (M1) and the ICE Brent Crude 9th month futures (M9) (left axis) relative to average ISPI between Q4Y03 and Q1Y12 (right axis). The two series have a correlation of -0.54 (p.0009) (Source of futures data is DataStream).



Since inventory and sales data for many of the companies is incomplete[11], it is possible that the ISPI measure shown in Figure 1a is biased by the entry into the index of a company. Accordingly, as a robustness exercise we calculate ISPI for the five companies with continuous data throughout the period of analysis (86 quarters; see Table 2). Figure 1b shows the ISPI based on these firms only. The trend is similar, though there is less of an increase in ISPI post 2000. Figure 1c reports the ISPI measure based on 12 of the 15 companies using the days to sales measure.[12] The ISPI based on days to sales also shows an increase in the width of the one standard deviation around the ISPI measure post Q3 of 2003. This is again consistent with a subset of firms holding greater inventories of oil in anticipation of the rising crude oil price.

As noted in section 2.1, companies can ‘speculate’ either through the riskless contango and carry trade or through a risk momentum trade. In order to shed light on which of these trades may have been important in the buildup in inventories we plot in Figure 2, which is the futures spread (font month futures minus 9 month futures) relative to ISPI around the period of interest (Q4Y03 and Q1Y12). It would seem that the momentum trade will have at least initiated the process since the rise of ISPI starts around Q4 of 2004 and the oil market does not enter contango until Q2 of 2005. However, as the market goes further into contango in Q1 2006, ISPI seems to respond by spiking up two quarters later (Q3 2006). As might be expected under a speculation hypothesis, there is a negative correlation between spread and ISPI of 0.54 which is significant at the 1% level.

[11] This is due to some companies reporting half-yearly rather than quarterly over periods of the sample.

[12] We exclude Petrobras Brasilerio days to sales as it was an outlier. Days to sales data was not available for China Petroleum or Sasol.

Also it is worth observing that the periods of contango either side of Q4 2007 have very different causes and implication. The first period, Q2 2005 to Q3 2007, is the result of rising futures prices due to financialization (Chan *et al.* 2015). In the second period, Q3 2008 to Q1 2011, the contango is caused by the collapse of near futures prices and spot prices following the Global Financial Crisis. Moreover, in the former case inventories were rising when global oil supply was supposedly tight, while in the latter case, rising ISPI will reflect a glut of supply. Thus it could be suggested that in the first period the contango and carry trade exacerbated the oil price spike, while in the second period it served to bring the spot and futures market back into balance. This highlights the nuanced argument that, depending on the context, the contango and carry trade can either be detrimental (and consistent with the notion of 'excessive speculation'[13]) or beneficial to the oil market.

Overall, the descriptive evolution of ISPI in Figures 1a to 1c, illustrates declining ISPI pre the speculation period and an increasing ISPI during the speculation period. This evidence is broadly consistent with the evidence presented by Kaufmann (2011) and Singleton (2014) for the US, namely that the momentum market in oil prices between 2003 and 2008 was associated with rising inventories. As such, we add global evidence to their US findings. Further, the $\pm$ one standard deviation of ISPI highlights the heterogeneity of oil company behavior in the period leading up to the oil price spike. Finally, Figure 2 highlights that it is likely that both momentum and contango and carry trades contributed to rising inventories. Next, we formally test for significant breaks in the inventory holdings for each firm and the ISPI scaled inventory.

[13] See earlier discussion in Footnote 1 and Fattouth *et al.*, (2013).

Table 3: Bai-Perron Structural Break Tests for Inventory/Sales, Days to Sales and the Crude Oil Price

This table reports the results of the Bai-Perron structural break tests using the global information criterion for individual company time series and the ISPI time series based on the five (ISPI_5) and six (ISPI_6) largest oil companies in the sample with data available in each quarter. The results show the number of breaks and the quarterly time periods over which the breaks occur for the scaled inventory and days to sales measures.

Time Series	Breaks	Pre-Speculation Period 1990 Q4 to 2004 Q2 (defined by Oil Structural Break)				Speculation Period	Post Bubble (2008 onwards)				
Panel A: Inventory/Sale											
British Petroleum	3	1990Q4 - 1993Q4	1994Q1 - 1997Q3	1997Q4 - 2004Q4		2005Q1 - 2012Q1					
Royal Dutch Shell	3	1990Q4 - 1994Q3	1994Q4 - 1999Q3	1999Q4 - 2005Q2		2005Q3 - 2012Q1					
Statoil	3	1998Q4 - 2000Q3	2000Q4 - 2006Q4			2007Q1 - 2009Q1		2009Q2 - 2012Q1			
Total SA	2	2000Q4 - 2004Q4				2005Q1 - 2008Q4		2009Q1 - 2012Q1			
Chevron	3	1990Q4 - 1994Q2	1994Q3 - 2000Q1	2000Q2 - 2008Q3				2008Q4 - 2012Q1			
Conoco Phillips	3	1990Q4 - 2001Q2	2001Q3 - 2004Q2			2004Q3 - 2008Q4		2009Q1 - 2012Q1			
Exxon Mobil	3	1990Q4 - 1995Q4	1996Q1 - 2004Q2			2004Q3 - 2008Q3		2008Q4 - 2012Q1			
Valero Energy	1	1990Q4 - 1994Q1	1994Q2 - 2012Q1								
Eni Spa	3	1999Q4 - 1999Q4	2000Q1 - 2004Q3			2004Q4 - 2009Q1		2009Q2 - 2012Q1			
Gazprom	1	2001Q1 - 2005Q3				2005Q4 - 2012Q1					
Lukoil	2	2002Q1 - 2003Q2	2003Q3 - 2008Q4					2009Q1 - 2012Q1			
Petrobras	2	2001Q2 - 2002Q3	2002Q4 - 2005Q1			2005Q2 - 2012Q1					
China Petroleum	2	2000Q3 - 2002Q3					2002Q4 - 2009Q3	2009Q4 - 2012Q1			
Sasol	1	1990Q4 - 1997Q3	1997Q4 - 2012Q1								
Repsol	1	1990Q4 - 2001Q3						2001Q4 - 2012Q1			
ISPI_5	3	1990Q4 - 1994Q4	1995Q1 - 1999Q2				1999Q3 - 2008Q4	2009Q1 - 2012Q1			
ISPI_6	3	1990Q4 - 1994Q4	1995Q1 - 2004Q4			2005Q1 - 2008Q4		2009Q1 - 2012Q1			
Panel B: Days to Sales											
British Petroleum	3	1992Q4 - 2000Q3	2000Q4 - 2002Q4	2003Q1 - 2005Q1		2005Q2 - 2012Q1					
Royal Dutch Shell	3	1990Q4 - 1995Q3	1995Q4 - 2000Q2	2000Q3 - 2005Q4		2006Q1 - 2012Q1					
Statoil	3	1999Q4 - 2001Q2	2001Q3 - 2006Q2			2006Q3 - 2008Q2		2008Q3 - 2012Q1			
Total SA	2	2002Q2 - 2005Q2				2005Q3 - 2009Q3			2009Q4 - 2012Q1		
Chevron	3	1990Q4 - 1995Q3	1995Q4 - 2000Q2	2000Q3 - 2008Q4				2009Q1 - 2012Q1			
Conoco Phillips	3	1990Q4 - 1994Q1	1994Q2 - 2001Q2	2001Q3 - 2004Q2		2004Q3 - 2012Q1					
Exxon Mobil	5	1990Q4 - 1993Q3	1993Q4 - 1996Q3	1996Q4 - 2001Q3	2001Q4 - 2004Q3	2004Q4 - 2008Q4			2009Q1 - 2012Q1		
Valero Energy	2	1990Q4 - 1994Q2	1994Q3 - 1999Q1	1999Q2 - 2012Q1							
Eni Spa	1					2007Q1 - 2008Q4		2009Q1 - 2012Q1			
Gazprom	4					2006Q2 - 2007Q4	2008Q1 - 2008Q3	2008Q4 - 2009Q3	2009Q4 - 2010Q3	2010Q4 - 2011Q4	
Lukoil	2	2002Q4 - 2003Q4	2004Q1 - 2006Q2			2006Q3 - 2012Q1					
Petrobras	5	2001Q4 - 2003Q3	2003Q4 - 2005Q2			2005Q3 - 2006Q4	2007Q1 - 2009Q1	2009Q2 - 2010Q3	2010Q4 - 2012Q1		
China Petroleum	4	2000Q4 - 2003Q1	2003Q2 - 2005Q1			2005Q2 - 2007Q4	2008Q1 - 2010Q2	2010Q3 - 2012Q1			
Sasol	1	1997Q4 - 2002Q3						2002Q4 - 2012Q1			
Repsol	4						2008Q3 - 2009Q2	2009Q3 - 2009Q4	2010Q1 - 2010Q3	2010Q4 - 2011Q2	2011Q3 - 2012Q1
Avg5_Days_Sales	3	1990Q4 - 1994Q2	1994Q3 - 1999Q4	2000Q1 - 2006Q3		2006Q4 - 2012Q1					
Avg6_Days_Sales	3	1990Q4 - 1994Q2	1994Q3 - 1999Q4	2000Q1 - 2005Q3		2005Q4 - 2012Q1					
Oil Price	2	1990Q4 - 2004Q2				2004Q3 - 2008Q2	2008Q3 - 2012Q1				

Figure 3 Oil price Structural Breaks

This figure shows the time series of the price of a barrel of crude oil. There are two structural breaks over the sample period. The first occurs at Q2 of 2004 and the second is at Q3 of 2007.

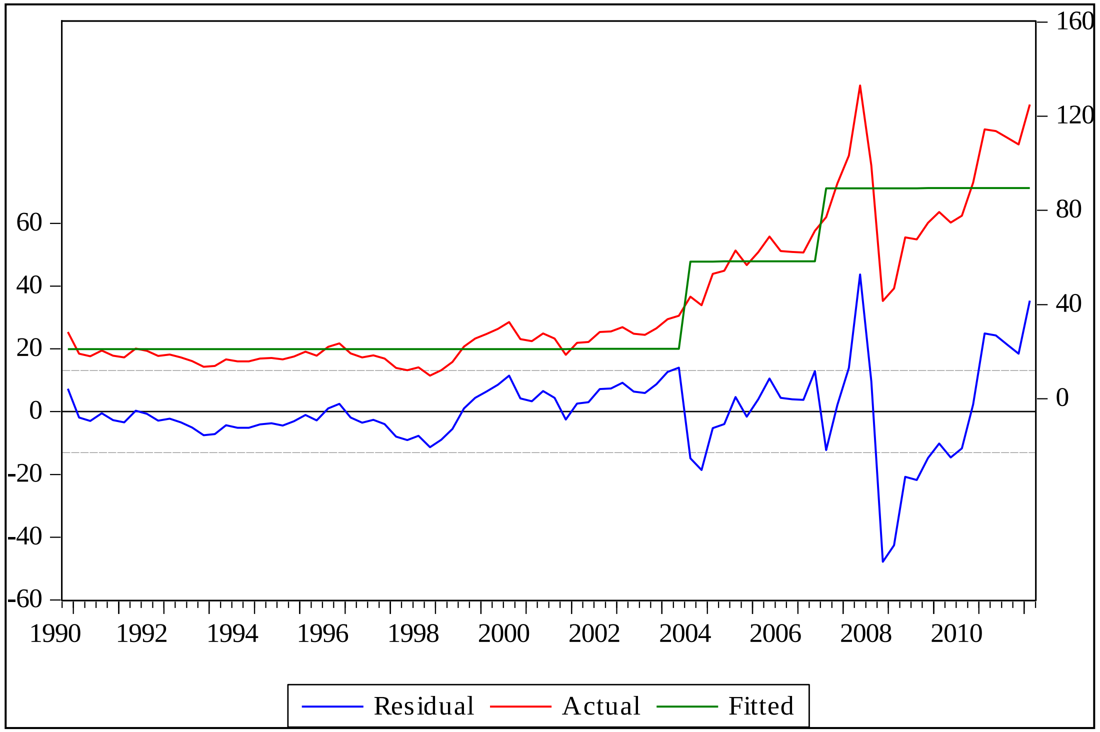
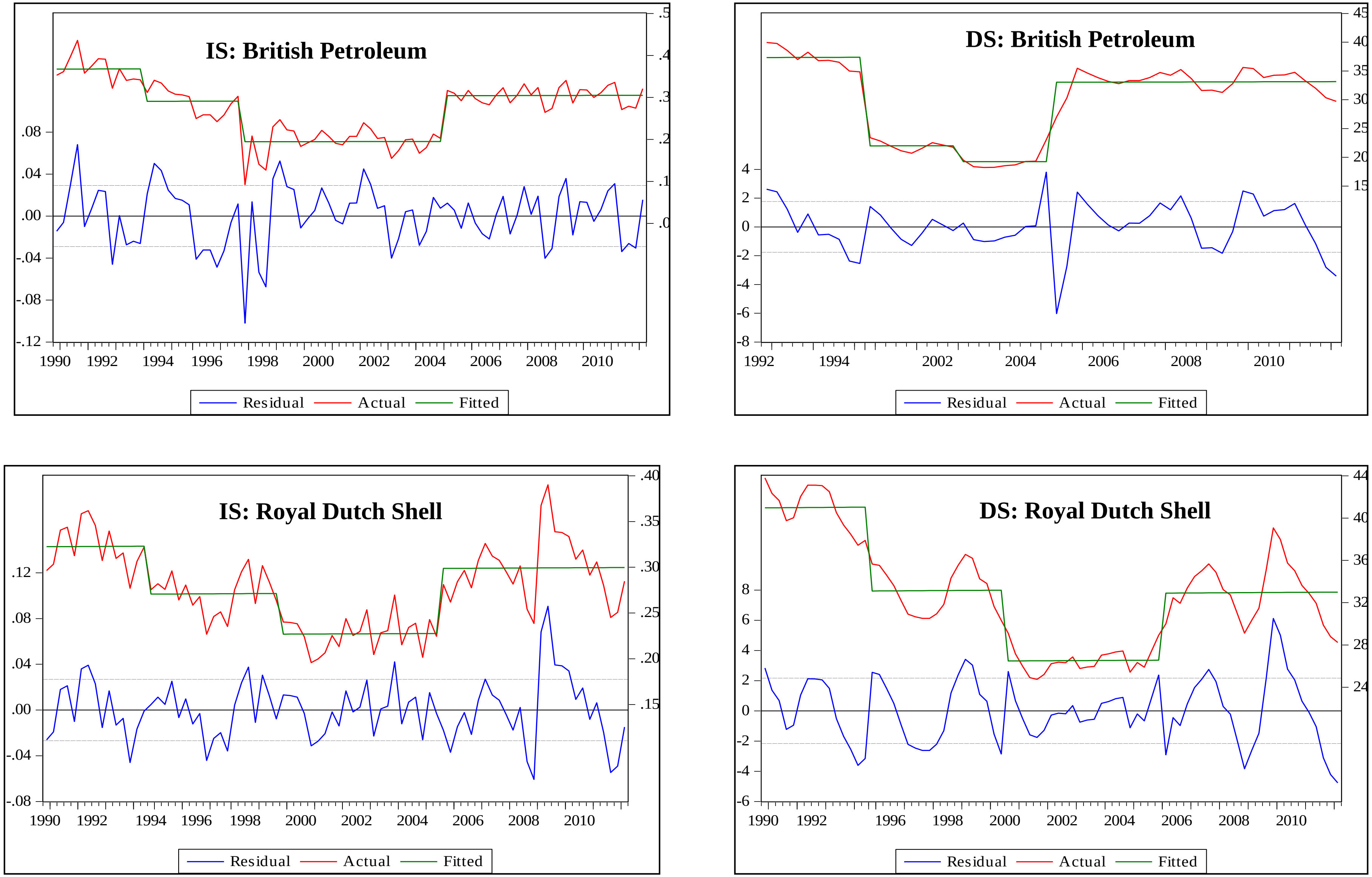


Figure 4: Structural Break Graphs for Individual Companies

The following graphs show the change in Inventory/Sales (IS) and days to sales (DS) measures for each of the oil companies that show a significant structural break in the time series of the scaled inventory data over the sample period. British petroleum, Royal Dutch Shell, Statoil, Total, Gazprom and Lukoil all experience positive structural breaks during the speculative period. Conoco, Exxon Mobil and Petrobras experience a negative structural break during the speculative period.



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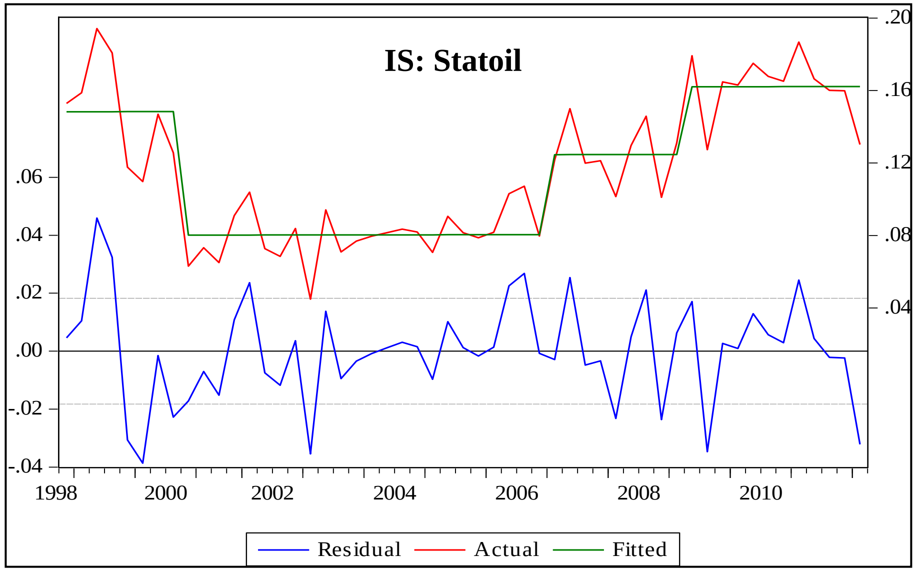

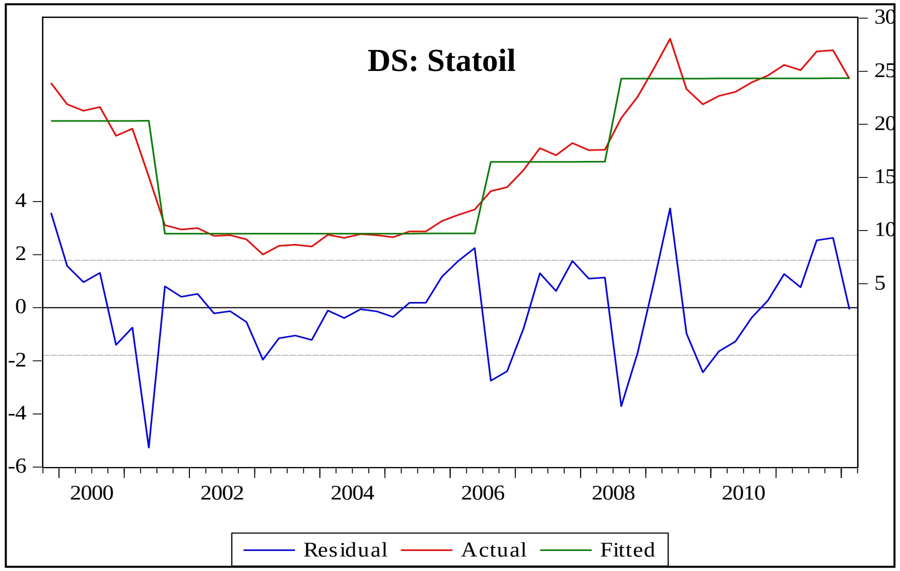

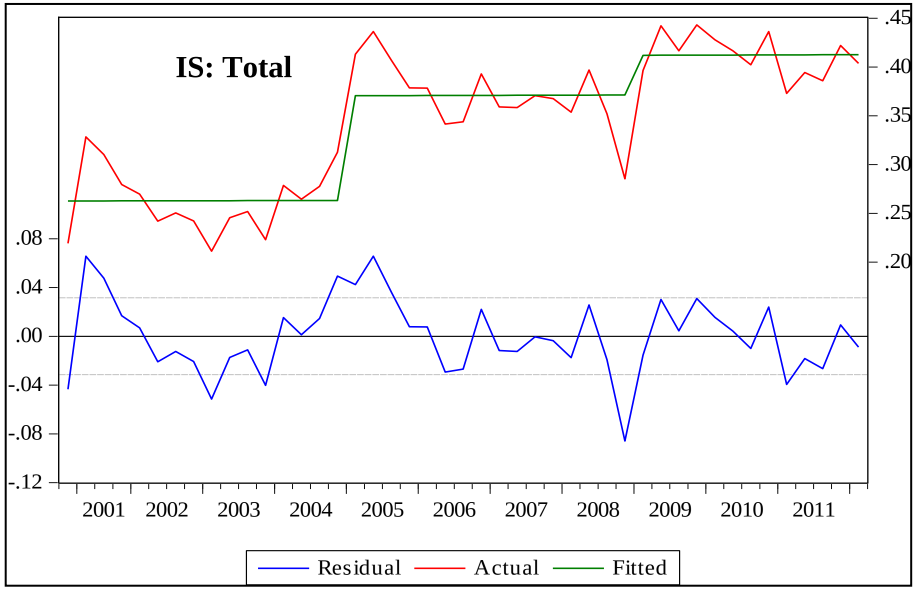

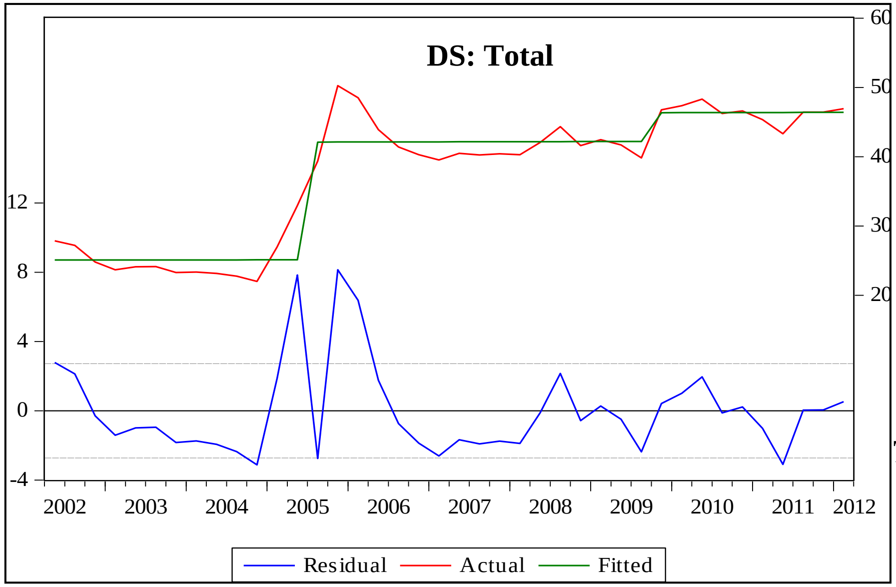

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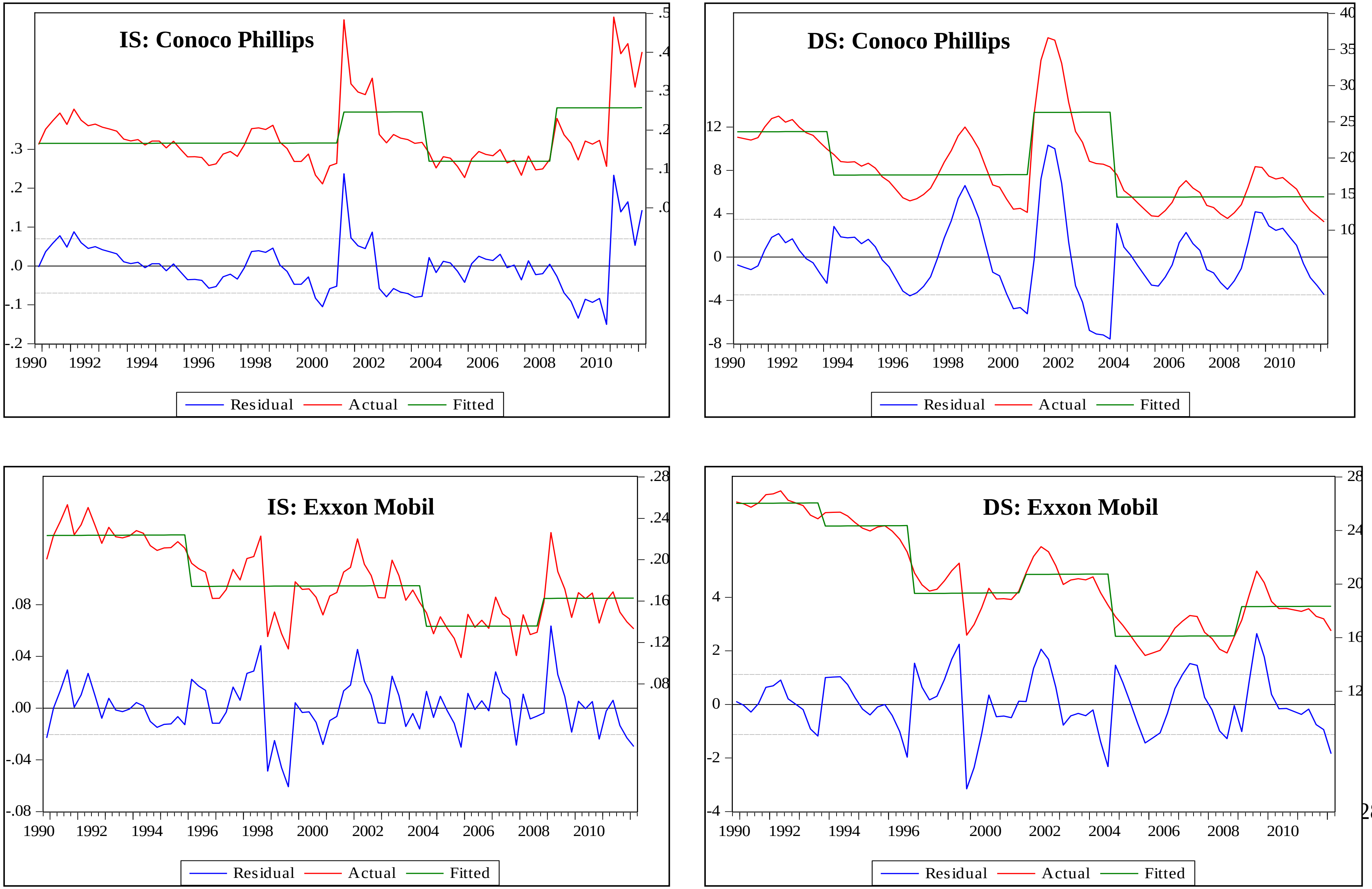

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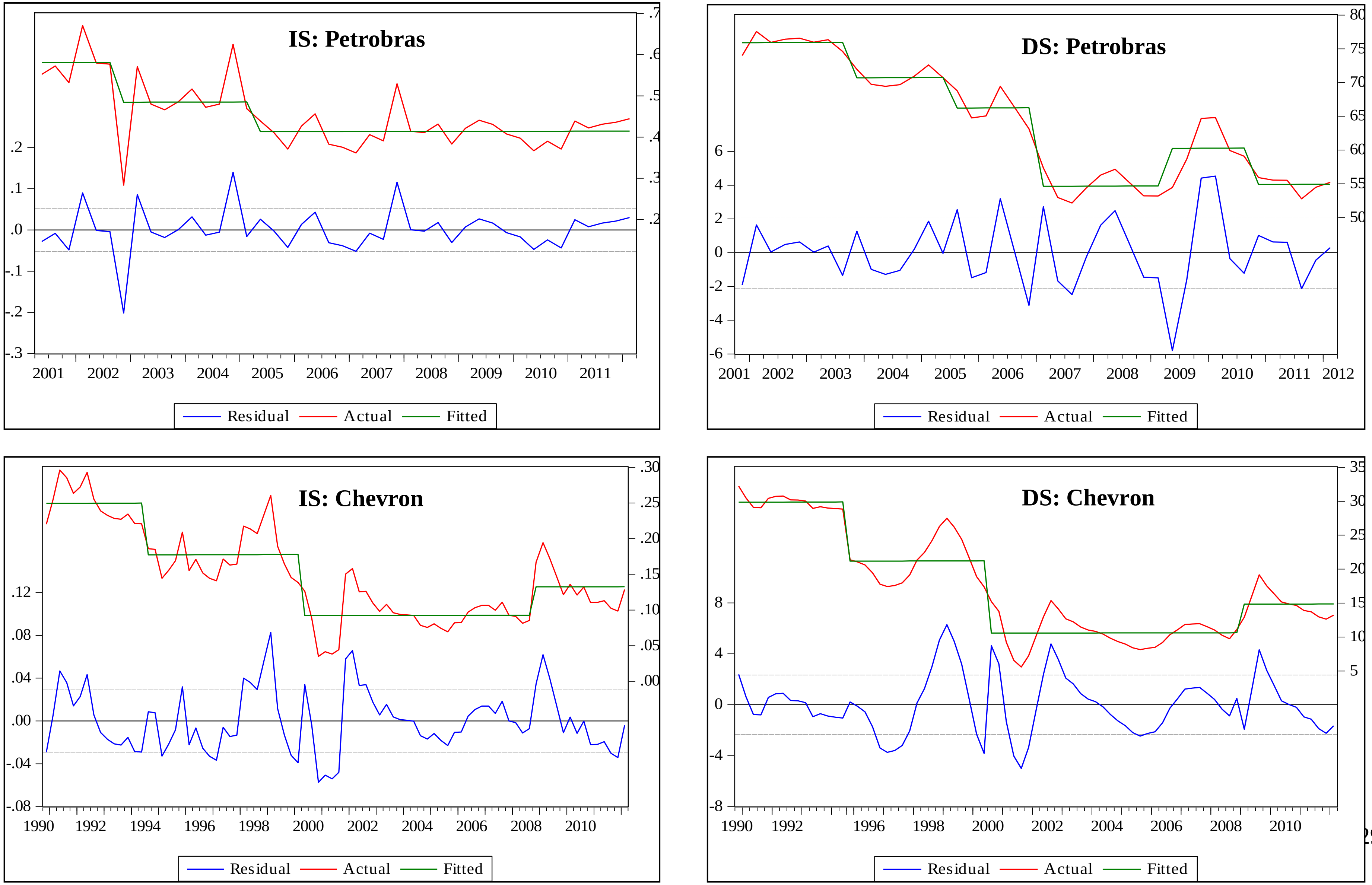

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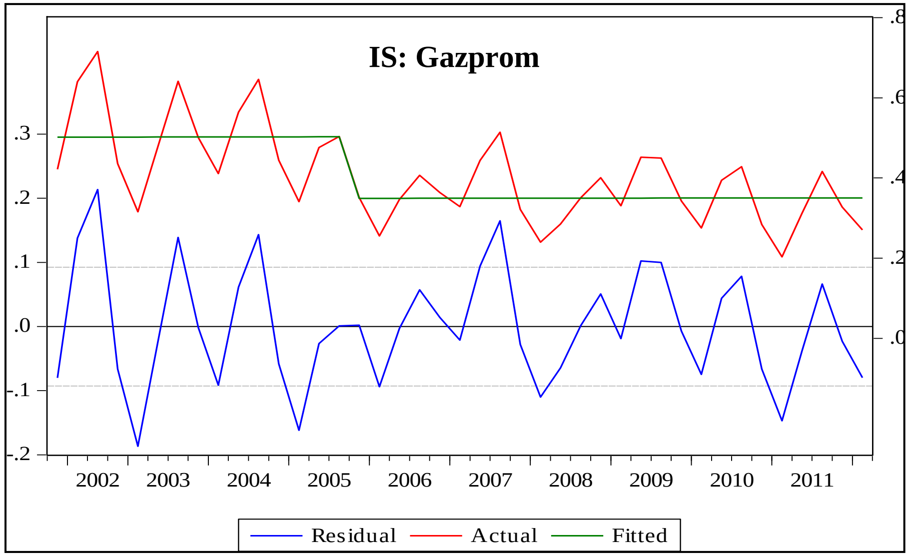

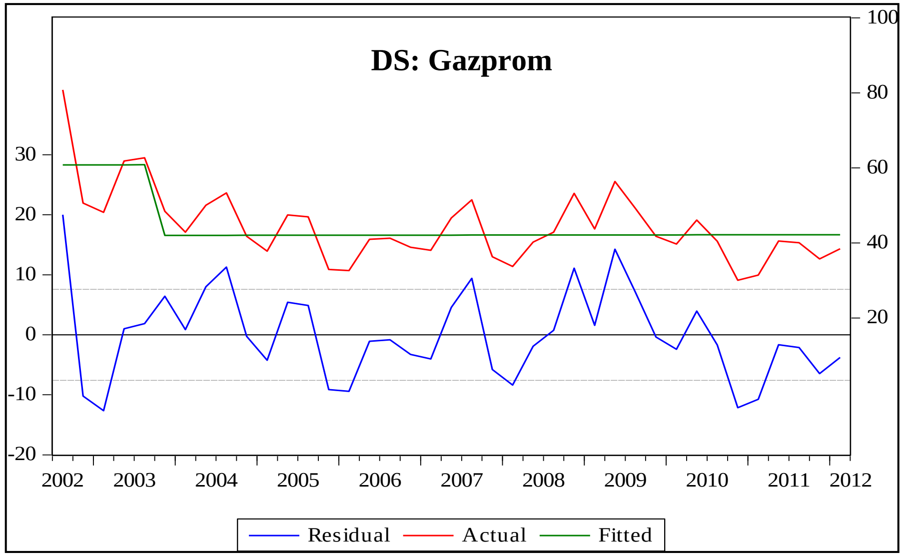

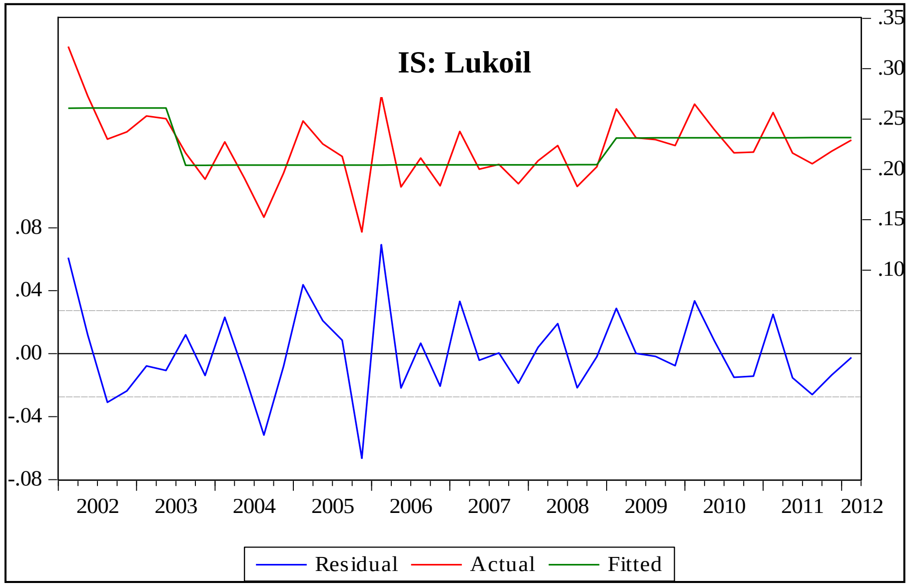

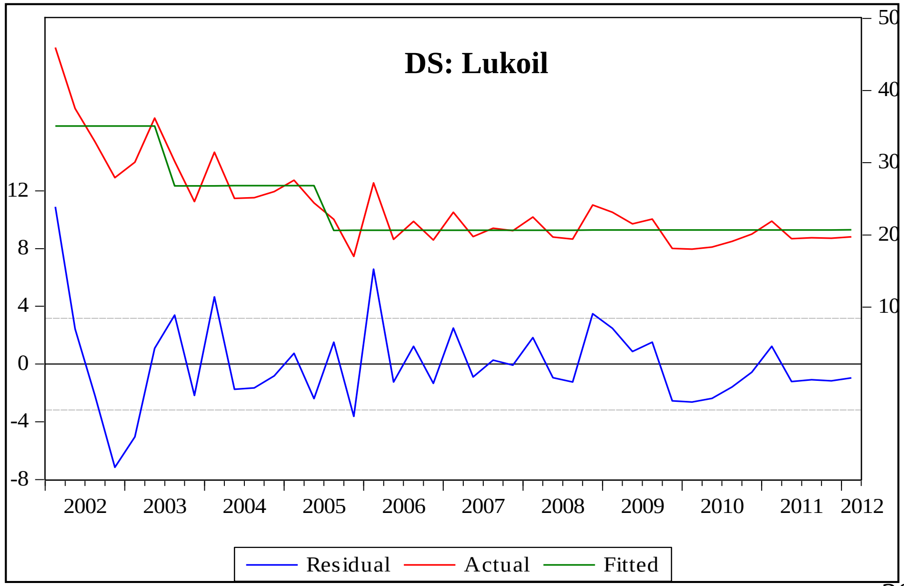

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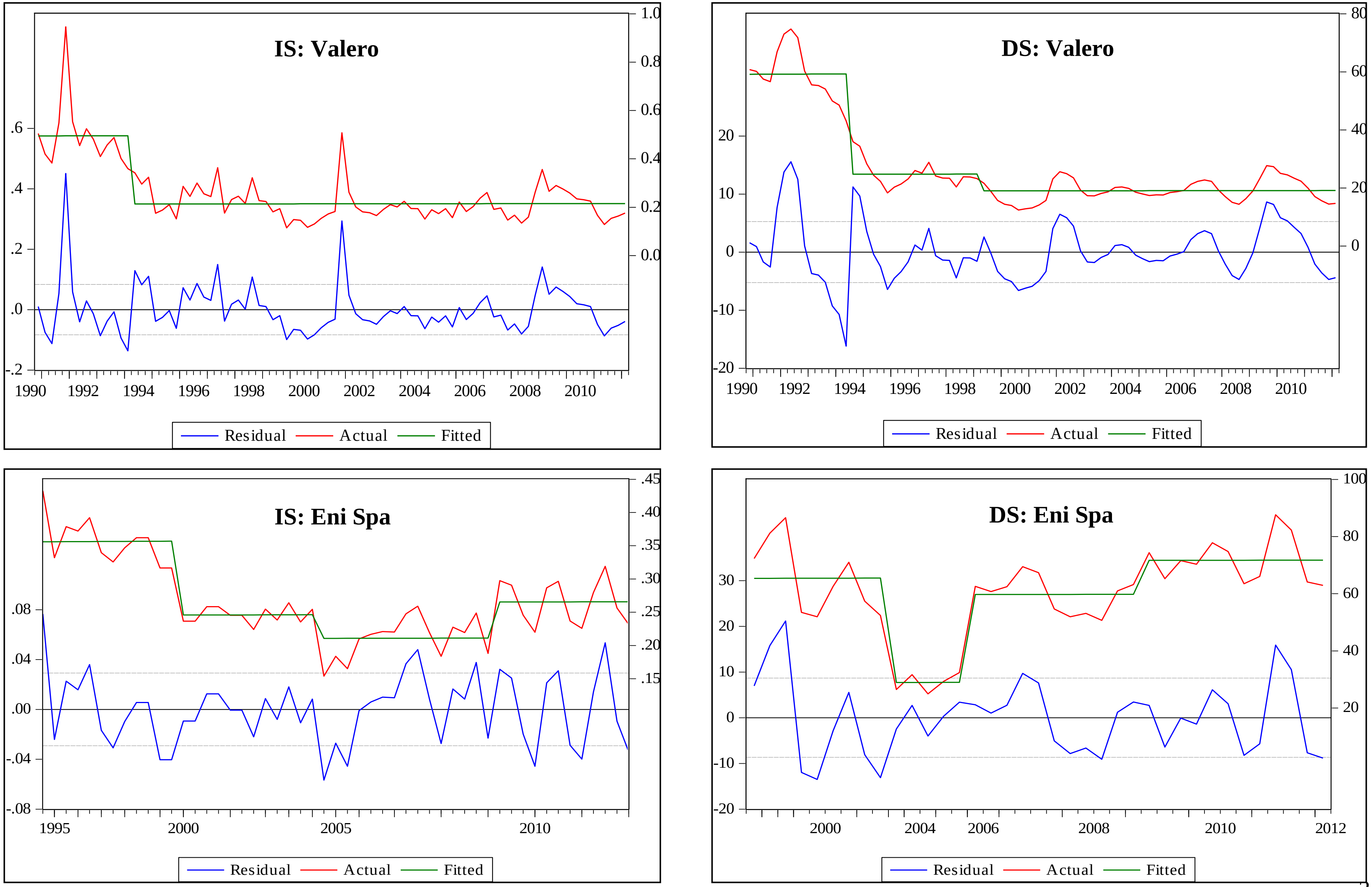

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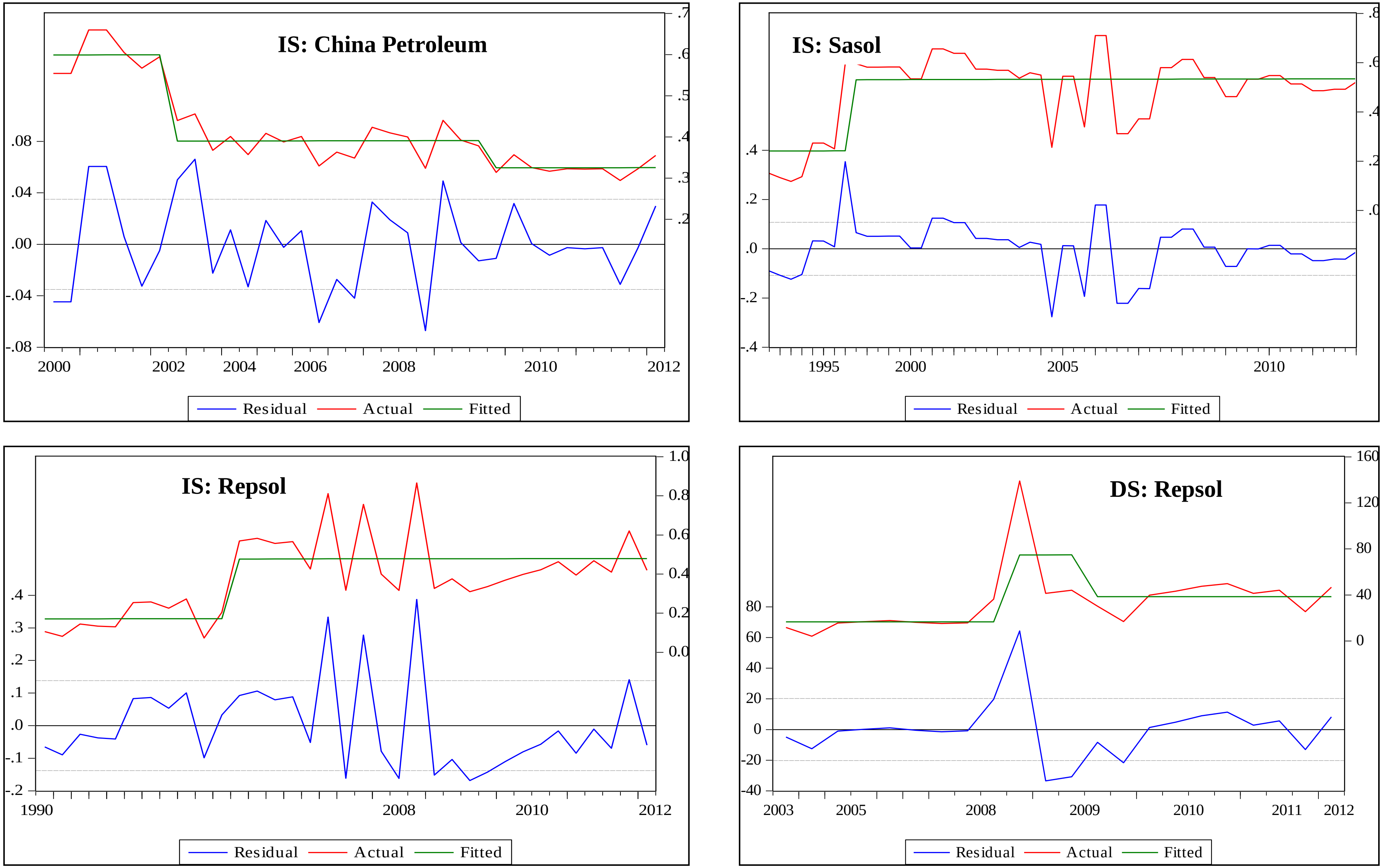

5.2. Structural Breaks

The Bai-Perron multiple structural breaks test using the global information criterion is an empirical test used to identify break points in the time series using the inventory scaled by sales and days to sales data for each company, the scaled inventory measures (ISPI_5 and ISPI_6), the average days to sales ($\bar{V}_t^{DS}$) and the Brent crude oil price from 1990 Q4 to 2012 Q1. The presence and sign of structural breaks can provide additional evidence from the accounting inventory numbers about the speculative behavior of companies involved in the physical oil market in the run-up to 2008, in particular if there is a structural break during the momentum or 'speculation period'. We define the speculation period as starting in Q3 of 2004 as delineated by a positive structural break in the oil price and ending in Q2 of 2008 as oil price peaked (see Table 3 and Figure 3).

There are no structural breaks for ISPI_5. Averaging may have smoothed out this series, so that we cannot interpret the lack of significance as evidence of no aggregate effect of speculation. ISPI_6, Avg5_Days_Sales and Avg6_Days_Sales all have structural breaks. Panel A of Table 3 reports the structural breaks using the inventory to sales data. Nine of the 15 companies tested experience a structural break during the speculation period. The break points shown in Panel B of Table 3 refer to the structural breaks using days to sales. Eleven of the 13 companies tested show a structural break during the speculation period. Individual graphs of the structural break time series reported in Figure 4 show positive breaks for British Petroleum, Royal Dutch Shell, Statoil, Total. Evidence of a positive structural break is contrary to expectations that inventories should be declining due to the tight oil market (supply contains). The findings suggest these firms may have been undertaking speculative positions on rising oil prices by holding more inventory. Conoco, Exxon Mobil and Petrobras all experience negative structural breaks, whereas Chevron, Gazprom, Lukoil, Valero, Eni, China, Sasol and Repsol show no sign of a structural break during the speculation period based on the inventory to sales measure.

The structural break analysis confirms the heterogeneity in inventory behaviour by the various commercial traders. Those choosing to speculate on oil price display positive breaks in inventory. In contrast, companies with no or negative structural breaks show no evidence of speculative behaviour. These findings support H1 and H3.

5.3. Operating Profit Model [14]

As a further test, we estimate equation (3) during the pre-speculation period (Q4 of 1990 to Q2 of 2004) and again during the speculation period (Q3 of 2004 to Q2 of 2008). The results for the estimation of equation (3) are reported in Table 4.

The estimates for the model during the pre-speculation period are reported in Panel A. It is interesting to note that 9 of the 12 models reported have a negative α_2 coefficient which is consistent with H2. The aggregate Average_5 model also has a significant negative coefficient, which again lends support to H2. Panel B shows the results for the model estimated during the period where speculation may have occurred (Q3 2004 to Q2 2008 as defined earlier). Consistent with H4, BP, Shell and Total all have positive α_2 coefficients and experience a positive structural break in their scaled inventory measures. The coefficients for Shell and Total are significant at 5% and 1%, respectively. The aggregated measures, Average_5 and Average_6 also have positive, significant coefficients consistent with H4. These findings provide evidence to support speculative behavior. Conoco Phillips, while also reporting a positive coefficient on the lagged change in barrels of oil held in inventory during the speculative period, does not support H4 because the firm has a negative structural break.

[14] This analysis is not undertaken using our alternative inventory measure, days to sales, since it is an average over time and using it would violate the lag structure in equation 3. As noted in Table 1, days to sales is calculated as the average of the most recent four quarters of inventories divided by the sum of the cost of goods sold (using a 12 month moving average) divided by 360.

It is also worth noting that Gazprom and Valero both have a positive α_2 coefficient, consistent with H4, however neither of these coefficients are significant.[15]

The α_2 coefficient for Total switches from negative to positive when moving from the pre-speculation to the speculation period. BP and Royal Dutch both maintain a positive α_2 value for both periods. Royal Dutch has a highly significant positive coefficient during the speculative period. Hence, there is some evidence to suggest a switching behavior may be present.

The results show that in the case of Royal Dutch Shell, Total and Average_6 the positive relationship between change in EBITDA and quantity of inventory held seems to be material. The finding for Total is consistent with H2 and H4. The results for Shell, Average_5 and Average_6 are consistent with H4. During periods of declining or flat oil prices, inventory will be negatively related to company operating profitability. Commercial traders will try to minimize inventory holdings. However, as the oil price increases the relationship between profitability and inventory switches from negative to positive and becomes stronger for traders experiencing a positive structural break in inventory following the commencement of the momentum market.

[15] There is insufficient data to test the model for Gazprom in the period 1990 Q4 to 2004 Q2. Note there is also insufficient data to estimate the models for China Petroleum, Eni, Repsol and Sasol in either period.

Table 4: Predictive Model of Profit Using Inventory

This table reports the coefficients for the model given in Equation (4). The model is fitted over the pre-speculation period (Q4 of 1990 to Q2 of 2004) and the speculation period (Q3 of 2004 to Q2 of 2008) with the latter defined by structural breaks in the oil price.

$$\Delta EBITDA_{i,t} = \alpha_1 + \alpha_2 \Delta Q_{i,t-1} + \alpha_3 \Delta P_t + \alpha_4 \Delta Cash_{i,t} + \alpha_5 \Delta LIQ_{i,t} + \alpha_6 \Delta LEV_{i,t} + \alpha_7 \Delta Sales_{i,t} + \alpha_8 \Delta PPE_{i,t} + \varepsilon_{i,t}$$

Where Q is the number of barrels of crude oil determined from the inventory data in the balance sheet, P is the price of crude oil, Cash is the value of cash and cash equivalents disclosed in the current assets, LIQ is the quick ratio, LEV is the ratio of long-term debt to total shareholder equity, Sales is revenue reported in the income statement and PPE is the value of property, plant and equipment disclosed in the balance sheet.

Panel A				**1990 Q4 to 2004 Q2**					
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	Speculative SB
British Petroleum	-487 *	**2.8**	35	-0.45 **	14,169 ***	9,748	0.25 ***	0.02	Positive
Royal Dutch Shell	-101	**4.5** *	138 ***	0.12	-151	1 *	0.09 **	0.00	Positive
Statoil	-102	**-13.1**	30	0.07	832	-1,747 *	0.28 ***	-0.02	Positive
Total SA	62	**-1.3**	21	0.07 *	-2,521	17,681	0.18 ***	0.05	Positive
Conoco Phillips	22	**-8.2** ***	9	0.04	76	347	0.25 ***	-0.05 ***	Negative
Exxon Mobil	-93	**-0.8**	-18	0.19 ***	3,633 ***	-12,974 **	0.13 ***	0.00	Negative
Lukoil	-23	**-7.8**	36 *	-0.36	384	-2,728	0.02	0.07	Negative
Petrobras	-47	**-6.3**	23	0.04	-480	315	0.30 **	0.01	Negative
Chevron	-40	**4.6** *	34	0.21	2,289	-3	0.11 ***	0.02	None
Valero Energy	-2	**-3.1**	4	0.08	12	-120	0.09 ***	0.02	None
Average_5	5	**-6.0** *	54 **	0.51 ***	-4,620 *	-3,545	0.15 ***	-0.08 ***	Positive
Average_6	-14	**-1.4**	37 *	0.33 ***	-2,888 *	-1,956	0.14 ***	-0.04 *	Positive
Panel B				**2004 Q3 to 2008 Q2**					
British Petroleum	-224	**29.2**	150 **	0.15	-15,540	57,282	0.13 *	-0.45	Positive
Royal Dutch Shell	-716	**21.6** **	238 ***	0.37	-11,565	0.2	0.03	-0.06	Positive
Statoil	512	**-36.5**	15	-0.19 **	7,761 ***	30,266 ***	0.69 ***	-0.17 ***	Positive
Total SA	-32	**12.3** ***	73 ***	0.01	11,825 *	7,860	0.21 ***	-0.20	Positive
Conoco Phillips	246	**57.4**	-3	-0.30	-3,084	-2,685	0.16	0.02	Negative
Exxon Mobil	308	**-13.4**	-52	0.03	3,275	-130,851	0.16 ***	-0.08	Negative
Gazprom	-772	**28**	-22	-0.06	6,623 *	228	0.42 **	0.19	Negative
Lukoil	109	**-6.1**	-5	0.85	-230	-20,538	0.11 **	-0.01	Negative
Petrobras	-399	**-39.4**	60	0.00	-1,971	-5,954	0.32 ***	-0.03	Negative
Chevron	-56	**-11.9**	-27	0.47 **	-10,304	-11,948 *	0.21 **	-0.10	None
Valero Energy	104	**25.8**	-24	0.15	-1,838	4,522	0.17 **	-0.05	None
Average_5	235	**35.8** *	-11	0.42 **	-13,058	16,221	0.23 ***	-0.19	Positive
Average_6	535.4	**40.6** **	-11	0.35	-16,210	22,080	0.25 ***	-0.29	Positive

6. Conclusions

This study uses accounting inventory data to determine if there is evidence to suggest that companies involved in the physical oil market have been speculating in the run-up to the 2008 oil price hike. Using quarterly inventory data over the period 1990 Q4 to 2012 Q1 for a sample of 15 of the largest listed oil companies in the world, we derive two scaled measures of oil inventory holdings based on the ratio of inventory to sales and the days to sales measures. Declining ISPI up to the early 2000s is consistent with firms minimizing inventory for efficiency sake; then ISPI starts to increase, suggesting physical inventories could have contributed to the run-up in oil price. This is consistent with Kaufmann's (2011) evidence for the United States. The standard deviation of ISPI starts to increase in early 2000, suggesting greater heterogeneity in inventory behavior.

A further examination of the heterogeneous behavior of oil companies based on the Bai-Perron (1998) structural break tests applied to the ratio of inventory to sales shows that nine of the 15 companies tested experience a structural break during the speculation period. British Petroleum, Royal Dutch Shell, Statoil and Total all have significant, positive structural breaks during the speculation period. Conoco, Eni, Mobil Exxon and Petrobras experience negative structural breaks in the speculation period, while Chevron, China, Gazprom, Lukoil, Repsol, Sasol and Valero show no evidence of structural breaks. Evidence of a positive structural break in inventory as oil prices increase is suggestive of commercial traders speculating, though it is not the only possible explanation for a positive break (see below). Conversely, negative or no structural breaks during the speculation period are consistent with non-speculative behavior.

We also examine the relationship between changes in operating earnings before depreciation and amortization to changes in oil inventory over the pre-speculation and speculation period. The latter is defined by structural breaks in the oil price. We report some evidence of switching in the coefficients for the change in the quantity of inventory variable over the two periods. There is also consistent but statistically insignificant sign changes in the sensitivity of the quantity of oil held by firms to changes in operating profitability measured by EBITDA. This is consistent with evidence by Singleton (2014). The conclusion based on these models is that switching has not materially affected performance, save for the cases of Royal Dutch Shell and Total. The aggregated measures Average_5 and Average_6 also lend support to speculative behavior.

To conclude, our evidence from ISPI (Figures 1a, 1b and 1c) and the structural breaks are strongly suggestive that at least some oil companies were involved in speculative activity, though this does not represent 'smoking gun' unassailable proof that they did so – the possibility remains that other factors caused individual inventory numbers to increase. For instance lengthening supply chains could be a plausible alternative explanation and it would seem this might explain the positive structural break for Statoil which started delivering oil beyond Europe in the relevant period. However, it seems unlikely that all positive breaks can be explained by a third factor. Overall, our results are highly consistent with the evidence presented in Kaufmann (2011) and thereby add to the 'smell test' that physical markets speculation could have contributed to the run-up in prices between 2004 and 2008.

Acknowledgements and Conflicts

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References

Chan, L., Nguyen, C., & Chan, K., 2015. A new approach to measure speculation in the oil futures market and some policy implications. *Energy Policy,* 86, 133-141.

Bai, J. & Perron, P., 1998. Estimating and testing linear models with multiple structural changes. *Econometrica*, 66(1), 47-78.

Buyuksahin, B., & Harris, J., 2011. Do speculators drive crude oil futures prices? *Energy Journal*, 32(2), 167-202.

Diaz-Rainey, I., Siems, M., & Ashton, J., 2011. The financial regulation of energy and environmental markets. *Journal of Financial Regulation and Compliance*, 19(4), 355-369.

Dvir, E., & Rogoff, K. S. (2010). The Three Epochs of Oil. Harvard University, Cambridge, MA.

Fattouth, B., Kilian, L., & Mahadeva, L., 2013. The role of speculation in oil markets: What have we learned so far? *The Energy Journal*, 34(3), 7-33.

Hamilton, J. D., 2009. Causes and consequences of the oil shock of 2007 – 2008. Brookings Papers on Economic Activity, (Spring) 215-283.

Hamilton, J. D., 1996. This is what happened to the oil price-macroeconomy relationship. *Journal of Monetary Economics*, 38(2), 215-220.

Hamilton, J. D., 1983. Oil and the macroeconomy since World War II. *The Journal of Political Economy*, 228-248.

Irwin, S., & Sanders, I., 2012. Testing the Masters Hypothesis in commodity futures markets. *Energy Economics*, 34, 256-269.

Kaufmann, R., & Ullman, B. (2009). Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and futures prices. *Energy Economics*, 31, 550-558.

Kaufmann, R. K., 2011. The role of market fundamentals and speculation in recent price changes for crude oil. *Energy Policy*, 39, 105-115.

Khan, M. S., 2009. *The 2008 Oil Price" Bubble"*. Peterson Institute for International Economics. Policy Briefing (No. PB09-19).

Kilian, L., 2009. Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review*, 99(3), 1053-1069.

Kilian, L. & Murphy, D., 2013. The role of inventories and speculative trading in the global market for crude oil. *Journal of Applied Econometrics*, 29(3), 454-478.

Lechthaler, F., & Leinert, L., 2012. Moody oil – What is driving the crude oil price? Working paper. Center of Economic Research at ETH Zurich, Swiss Federal Institute of Technology, Zurich.

Narayan, P. K., & Narayan, S., 2014. Psychological oil price barrier and firm returns. *Journal of Behavioral Finance*, 15(4), 318-333.

Narayan, P. K., & Sharma, S. S., 2011. New evidence on oil price and firm returns. *Journal of Banking & Finance*, 35(12), 3253-3262.

Silvennoinen, A., & Thorp, S., 2010. Financialization, crisis and commodity correlation dynamics. *Journal of International Financial Markets, Institutions & Money*, 24, 42-65.

Singleton, K. J., 2014. Investor flows and the 2008 boom/bust in oil prices. *Management Science*, 60(2), 300-318.

Stoll, H., & Whaley, R., 2009. Commodity index investing and commodity futures prices. *Journal of Applied Finance*, 20(1), 7-46.

Tang, K., & Xiong, W., 2012. Index investment and the financialization of commodities. *Financial Analysts Journal*, 68(6), 54-74.

Ye, M., Zyren, J., Shore, Y., 2005. A monthly crude oil spot price forecasting model using relative inventories. *International Journal of Forecasting*, 21, 491-501.

Ye, M., Zyren, J., Shore, Y., 2006. Forecasting short-run crude oil price using high- and low-inventory variables. *Energy Policy*, 34, 2736-2743.

Vivian, A., & Wohar, M., 2012, Commodity volatility breaks. *Journal of International Financial Markets, Institutions & Money*, 22(2), 395-422