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A State-of-the-Art Review of Finance Research in Physical and Financial Trading Markets in Crude Oil

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1. Introduction

It goes without saying that crude oil is important for both developed and emerging economies, with crude oil-related expenditures representing a significant proportion of total economic inputs, and an even more substantial share of total energy consumption. For example, energy expenditures of about $1,233 billion in the US currently account for some 8.8% of its GDP (from a high of 13.7% in 1981), with crude oil products (including distillate, jet fuel, liquefied petroleum gas, and gasoline) representing some 35.27% of total end-use energy expenditure, ahead of 23.56% for natural gas and 19.76% for coal. Of this, the residential, commercial, and industrial sectors respectively account for 11.4%, 5.9% and 47.1% of end-use expenditure and the transportation sector the remainder. It is then clear to see economic activity positively depends on crude oil requirements and expenditures. It also explains why Hamilton (1983) very early concluded that a dramatic increase in the price of oil has preceded almost every post-World War II recession in the US. Accordingly, as a key factor input, crude oil price changes have the potential to alter dramatically the financial performance of economies at large and the performance and behavior of the firms that operate within them. Hence, understanding the relationship between oil prices and various financial markets is paramount, and there is a role for finance research in this regard.

For the most part, the finance discipline has addressed two main bodies of research in the physical and financial trading markets in crude oil. The first body of research has concerned the pricing dynamics of crude oil in both spot and derivative markets. The purpose here, among other things, is to provide market participants with accurate price and volatility forecasts to facilitate capital budgeting plans, help develop corporate strategy, and better manage revenue streams and commodity risk. Important research substreams include the relationships between crude oil prices and downstream products, such as refined petroleum and heating oil, and their relationship with financial instruments, such as crude oil futures, forwards, and options (including convenience yield and the role of inventories) as a tool for improving risk management practices and price forecasts. They also include the relationship between crude oil prices and linked real assets, such as exploration lease contracts and oil reserves, to facilitate the valuation of projects and firms in the crude oil industry. A particularly well developed stream of finance research within this body of work concerns the market efficiency of crude oil prices. In contrast, a less developed but emerging area of

interest revolves around behavioral finance and the actions and impacts of heterogeneous agents in crude oil markets.

The second body of research relates to the role of crude oil as a factor input and thence its impact upon financial assets, especially equity. For the most part, this work examines whether oil prices constitute a source of systematic asset price risk and whether exposure to this risk varies across industries and even countries. This serves as a suitable complement to the macroeconomics literature with its particular focus on the impact of oil prices shocks at the economy level. The underlying rationale provided for the inclusion of oil prices within asset pricing models typically stems from the importance of crude oil to the economy. Crude oil price changes have the potential to alter significantly future cash flows of firms through their influence on the costs of factor inputs. However, the significance of an oil price factor is potentially industry dependent. For instance, the transportation industry is highly vulnerable to oil price increases owing to its heavy reliance on oil-based factor inputs, while revenues in the oil and gas industry are likely to benefit from increases in oil prices. Similarly, the ability of individual firms to pass on rising factor costs to customers and by differing degrees of oil price hedging complicates the detection of any indirect or direct impact of oil price changes on stock returns.

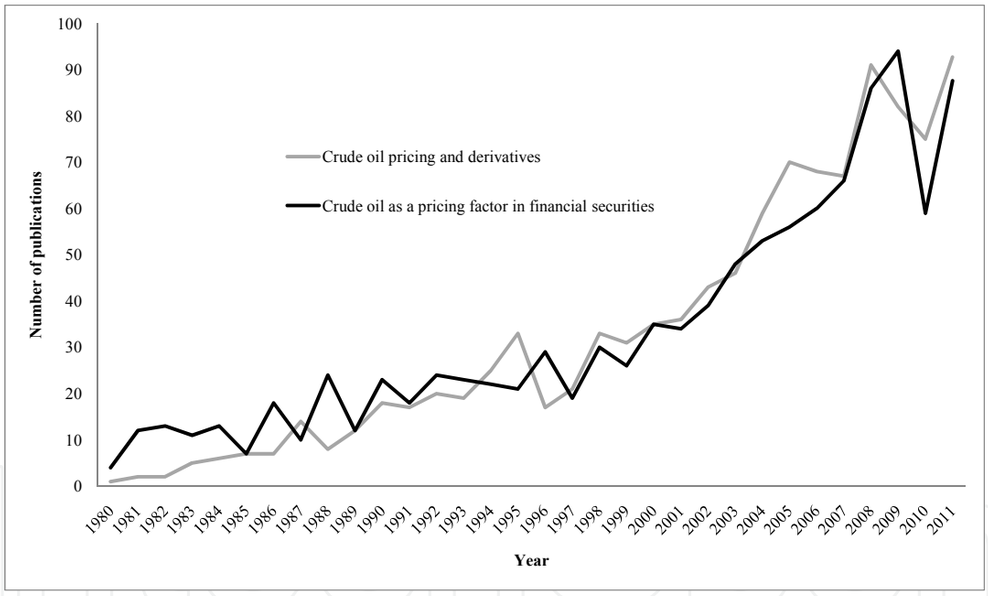


Fig. 1. Crude oil-related finance research, 1980–2011.

As shown in Fig. 1, interest in both of these areas of research has grown substantially in recent decades. The purpose of this chapter is then to survey comprehensively the burgeoning finance research as it relates to physical and financial trading markets in crude oil. Apart from discussing the objectives and purpose of crude oil-related finance research, the chapter also assesses the methods used by existing academic and industry researchers. This highlights the empirical problems that have received attention in the literature, and the efforts to overcome these problems. It therefore provides guidance to those conducting finance-related research in crude oil and an aid for crude oil industry analysts, regulators, policymakers, practitioners and other stakeholders interpreting the findings of these studies.

Overall, the chapter serves to complement the other chapters in this volume concerning crude oil and encompassing the disciplines of engineering, chemistry, geology, geophysics, economics and management.

The remainder of the chapter comprises six sections. Section 2 details the scope of the review. Section 3 outlines the theory and empirical work on intertemporal price relationships in the physical and financial markets for crude oil. Section 4 discusses the theory and evidence on financial market efficiency in crude oil markets while Section 5 undertakes a similar process in considering crude oil as a pricing factor in financial markets. Section 6 provides a conclusion to the chapter and Section 7 lists the references used.

2. Scope and limitations of review

This chapter is concerned with finance research on the physical and financial trading markets in crude oil. While closely related, it is not the purpose of this review to address the sizeable macroeconomic literature concerning the fundamental determinants of crude oil prices and their subsequent impact on the prices of refined products (such as gasoline or distillate) or the impact of crude oil prices and expenditures on macroeconomic activity, growth, and development. Instead, we take crude oil prices as given and focus on their impact on the prices and other behavior of crude oil-related financial securities and derivatives.

Where possible, we concentrate on the most-recent finance research in crude oil markets published since 2000. We searched EconLit, the *Journal of Economic Literature* electronic database, to identify journal articles that were representative of the field. References therein helped identify other relevant articles. We also used Google Scholar to locate references not included in EconLit. Nonetheless, as it was not possible to include all of the studies discovered using this search procedure, we focus on the most significant and/or most readily accessible. Of the 73 references in the chapter, all are refereed journal articles with 19 (26%) published in *Energy Economics*, 4 (5%) in the *Energy Journal*, 3 (4%) each in the *Journal of Futures Markets* and the *Journal of Banking and Finance*. The remainder appears across a range of generalist economic, econometric, and finance journals. Only eight (11%) are published before the 2000s.

3. Intertemporal price relationships in crude oil markets

This first area of research concerns the relationships between the prices for crude oil in its physical (or spot) markets as the underlying consumption asset and the prices of crude oil commodity derivatives whose prices and conditions derive from these markets, as represented by crude oil futures and their associated options markets. Crude oil futures are standardized, exchange-traded contracts in which the contract buyer agrees to take delivery, from the seller, a specific quantity of crude oil at a predetermined price on a future delivery date. Crude oil options are contracts in which the underlying asset is a crude oil futures contract. The holder of a crude oil option possesses the right (but not the obligation) to assume a long (or bought) position (with a call option) or a short (or sold) position (with a put option) in the underlying crude oil futures at the specified strike (or exercise) price. This right ceases to exist when the option expires after the expiration date.

Currently, crude oil future and options contracts can be traded on a number of product-specific exchanges, of which the most important are the New York Mercantile Exchange (NYMEX) (part of the CME Group), the Intercontinental Exchange (ICE) (formerly the International Petroleum Exchange) and the Tokyo Commodity Exchange (TOCOM). The quotation of NYMEX Light Sweet Crude and Brent Crude oil options is in US dollars and cents per barrel and traded in lots of 1,000 barrels (42,000 gallons) of crude oil, as are the ICE Brent and West Texas Intermediate (WTI) crude oil options and futures. The TOCOM futures contract specifications for Middle East (monthly average of Dubai and Oman prices) crude oil are per 50 kiloliters (approximately 314.5 barrels) and are in Japanese yen.

As with other commodity futures and options, there are an array of market participants engaged in the trading of crude oil futures and options. These include commercial enterprises with a direct stake in the price of oil where these contracts serve as a hedging instrument for future production. For example, to protect themselves against falling cash (spot) market prices, producers, traders, and marketers can sell futures to lock in prices for future delivery, protecting the value of future crude oil sales. Futures can also serve as a hedging instrument to shift exposure to price risk. For example, refiners, traders, and marketers will buy futures to protect against their exposure to rising cash market prices. Similarly, professional energy traders trading refined crude oil product contracts, such as heating oil and unleaded gasoline, in tandem with crude oil futures can lock in the crack spread, or the theoretical cost of the refining margin between crude oil and its refined products. Finally, investors and speculators with no intention or required purpose for buying or selling crude oil can attempt to profit by buying or selling futures contracts.

As derivatives on a consumption asset (an asset held primarily for consumption purposes), crude oil and futures and options written on crude oil exhibit different price relationships to investment assets (assets held primarily but not solely for investment purposes), including precious metals and financial securities. For any asset in the absence of income and storage costs (including any physical outlay costs, interest charges and possibly a risk premium) the forward price will equal the spot price, otherwise arbitrageurs can buy (sell) the asset and enter short (long) forward contracts on the asset. Commodities that are consumption assets (like crude oil) provide no income but are subject to significant storage costs (as negative income). This would suggest that the futures price is equal to the spot price plus storage costs; otherwise, arbitrageurs would sell the commodity, save the storage costs, invest the proceeds at the risk-free interest rate, and take a long position in the futures contract.

However, users of crude oil as a consumption commodity are not indifferent between holding the physical commodity and futures contracts written on that commodity. For example, an oil refiner is unlikely to regard a futures contract on crude oil in the same way as crude oil held in inventory and therefore available for processing, now or later; benefits sometimes referred to as the convenience yield provided by the commodity. The intertemporal price relationship for crude oil will then reflect the market's expectation concerning its future availability such that the greater the possibility that shortages will occur, the higher the convenience yield. Conversely, if users of crude oil have large inventories, there is little chance of shortages in the future, and the convenience yield tends to be low.

Ultimately, the cost of carry reflects these factors. For crude oil, this is most determined by storage costs, such that the futures prices will differ from the spot price by an amount reflecting the cost of carry net of the convenience yield. If we assume fixed storage costs, the negative cost of the convenience yield will determine the costs of carry that positively relates to the level of inventory, approaching zero when inventory levels are very high. Higher convenience yields are then associated with futures prices less than the spot price, as a price premium exist for earlier, including immediate (spot), delivery.

Regardless of these circumstances, the price of crude oil futures will move to equal (and thus become an unbiased predictor of) the future spot price as time progresses. Otherwise if the futures price is higher (lower) than the spot price, arbitrageurs will sell (buy) the futures contract, buy (sell) crude oil and then make delivery, locking in a profit because the price of the contract sold (bought) is already higher (lower) than the amount spent buying (selling) the underlying asset to cover the position. The former situation, when the futures price is above the expected future spot price, is known as contango, the latter, when the futures price is below the expected future spot price, is known as normal backwardation.

An expanding number of studies have empirically examined aspects of these basic theoretical relationships, primarily with respect to crude oil futures and, to a lesser extent, crude oil options. One basic dimension of this research aims to examine prices, risk and convenience yields in futures prices. Lin and Duan (2007), for example, defined business cycle of crude oil as a seasonal commodity with demand/supply shocks and found that the convenience yield for crude oil indeed exhibited seasonal behavior, with the convenience yield for WTI crude oil highest in the summer, while that for Brent crude oil is the highest in the winter. In line with expectations, they also found that crude oil convenience yields are negatively related to inventory levels and positively related to interest rates. Lastly, Lin and Duan (2007) verified that physical oil prices are more volatile than futures prices at low inventory. Bhar and Lee (2011) also considered crude oil futures but with the aim of assessing market risk in futures markets. They found that the risk premium in the crude oil market is time varying and driven by the same sorts of risk factors as equity and bond markets.

Several other studies have also examined these fundamental relationships between the spot and futures markets in crude oil. Alquist and Kilian (2010), for instance, argued that despite their widespread use as predictors of the spot price of oil, oil futures prices tend to be less accurate as predictors than a default forecast of no change. Alquist and Kilian (2010) further argued that the relatively poor performance of futures prices in predicting spot prices was driven by strong variability of the futures price about the spot price, as captured by the oil futures spread, and in turn, the marginal convenience yield of oil inventories. Using a two-country, multi-period general equilibrium model of the spot and futures markets, Alquist and Kilian (2010) concluded that increased uncertainty about future oil supply shortfalls caused the futures spread to decline and the precautionary demand for oil to increase, thereby resulting in an immediate increase in the spot price. Thus, we may consider the negative impact of the oil futures spread as an indicator of fluctuations in the price of crude oil driven by precautionary demand.

Moshiri and Foroutan (2006) likewise argue that while movements in physical oil prices are complex, nonlinear models could provide useful forecasts of future price changes using

NYMEX daily crude oil futures prices from 1983 to 2003. Murat and Tokat (2009) likewise used the ability of futures prices to predict spot prices, but instead focused on the crack spread, justifying their choice on the basis that this was the most relevant signal to refiners and consumers primarily concerned with their exposure to the crack spread, but also by hedge funds speculating on the crack spread. Their results indicated the causal impact of crack spread futures on the spot oil market in both the long- and short-run. Further, crack spread futures were almost as good as the crude oil futures in predicting spot oil markets. In other work, Ye et al. (2010) investigated the changing relationship between the price and volume traded of short- and long-maturity NYMEX light sweet crude oil futures contracts and major changes in the physical crude oil market. They found, among other things, that excess production capacity in the physical market and electronic trading on the NYMEX futures markets played a substantial role in providing an early indication of market regime shifts in the other market and thus could potentially improve short-run crude oil spot price forecast models.

The question naturally arises as to the sources of prices in changes in futures outside their relationship with the physical market. Not unexpectedly, the most basic argument is that the macroeconomic fundamentals that drive the spot market in crude also drive the futures markets. For example, Zagaglia (2010) used factor-augmented vector autoregression models to examine the dynamics of NYMEX oil futures prices using a large panel dataset that includes global macroeconomic indicators and financial market indices, along with the quantities and prices of energy products. The results showed a strong linkage between crude oil futures markets and other financial markets. In other work, Casassus et al. (2010) used an equilibrium model to consider the correlation between inflation and oil futures returns. As a consumption good, Casassus et al. (2010) realistically found the positive correlation found in most earlier empirical studies, however other important sources of correlation related to monetary and output shocks. In fact, the reaction of central banks to these shocks was at least equally important in determining futures price changes.

Kaufmann and Ullman (2009), for one argued that the relationship between between spot and futures markets was relatively weak, arguing that long-term increase in oil prices be exacerbated by speculators, with innovations first appearing in spot prices for Middle Eastern crude oil prices and then spreading to other spot and futures prices. Yet other innovations first appear in the far month contract for WTI and likewise spread to other exchanges and contracts. Buyuksahin and Harris (2011) also considered the role of speculators in crude oil futures markets. Using a set of unique data from the US Commodity Futures Trading Commission, Buyuksahin and Harris (2011) tested the Granger causal relation between crude oil prices and the trading positions of various types of traders in the crude oil futures market. In contrast to Kaufmann and Ullman (2009), they found little evidence that hedge funds and other non-commercial position involved Granger-caused price changes. Lastly, it is understandable that the one-off macroeconomic and political shocks so important in driving prices and risk in physical markets in crude oil also drive futures prices. As just one example Chiu and Shieh (2009) found great success with modeling futures with autoregressive conditional heteroscedasticity models and found that high-volatility regimes in futures markets corresponded with the Gulf War, the Asian Financial Crisis, and September-11.

Apart from futures market behavior itself and its relationship with spot markets, a small body of work has examined the interrelationships between crude oil and other futures markets. One part of this exploits the obvious links between crude oil futures and related energy markets. For example, Westgaard et al. (2011) considered the relationship between gas oil and Brent crude oil using ICE futures. They found that in normal periods, energy futures prices, both crude oil-related and otherwise, are strongly correlated, but that during volatile periods corresponding to financial and environmental crises, the spread between gas and crude oil is likely to deviate, taking some time to revert to its original equilibrium value. In contrast to Murat and Tokat (2009), this was taken to suggest that energy traders and hedgers should treat the crack hedge with some care in volatile market environments.

Even farther afield, Cortazar and Eterovic (2010) used the prices of crude oil futures contracts to estimate copper and silver future prices. They found that a simple multicommodity model able to incorporate the nonstationary long-term process of oil was useful in accurately estimating long-term copper and silver futures prices, in fact achieving a much better fit than the available individual or multicommodity models. Du et al. (2011) similarly considered the relationships between crude oil futures markets and those of other (agricultural) commodities. They found that speculation and inventories were important in explaining the volatility of crude oil prices and that like many energy markets, crude oil futures prices displayed mean-reversion, an asymmetric relationship between returns and volatility, volatility clustering, and infrequent compound jumps. As to the relationships with agricultural futures markets like corn and wheat, Du et al. (2011) concluded these had tightened because of the role of ethanol production.

A final area relevant in the examination of crude oil futures markets concerns hedging. For the most part, empirical research here focuses on identifying an optimal hedge and determining it effectiveness, i.e. the reduction in the variability of a portfolio of spot assets and futures positions relative to an unhedged position. As a recent example, Yun and Hyun (2010) analyzed the hedging effectiveness over different hedge types and periods by Korean oil traders. As there, and in the wider commodity futures literature, while there are benefits to hedges, but the magnitude of the optimal hedges and their effectiveness can vary significantly. Numerous other studies have examined additional dimensions of crude oil spot and futures pricing (Agnolucci, 2009; Anderluh & Borovkova, 2008; Barros Luis, 2001; Crosby, 2008; Deaves & Krinsky 1992; Deryabin, 2011; Doran & Ronn, 2008; Fleming & Ostdiek, 1999; Hikspoors & Jaimungal, 2007; Horan et al., 2004; Hughen, 2010; Meade, 2010; Moosa & Al-Loughani, 1994; Moosa & Silvapulle, 2000; Paschke & Prokopczuk, 2010; Tokic, 2011; Trolle & Schwartz, 2009).

This final area offers one of the more useful directions for further research on crude oil futures. While there seems to be some empirical consensus that crude oil futures markets exhibit the basis relationships we expected, including with spot markets, hedging and other risk management strategies remain of interest. In particular, a greater academic understanding is required of the hedging behavior of both crude oil producer and consumer firms. This should permit market participants a more accurate insight into their own situation and possibly more effective solutions as well as facilitating the design of new and innovative derivative products on established and yet to be established exchanges.

4. Price behavior in crude oil markets

The second main area of finance research in crude oil markets concerns the efficient market hypothesis (EMH). While there has been strident criticism of the veracity of the EMH in recent years, particularly by the behavioral finance literature, it remains (along with asset pricing models) one of the original and main areas of finance research. In essence, the EMH assumes that market participants have rational expectations, that on average the market is correct (even if no individual is), and that whenever new and relevant information appears, participants update their expectations appropriately. Importantly, there is no requirement that participants behave rationally in response to this information, beyond the usual rational utility maximizing assumptions made in most orthodox finance models. As such, when faced with new information, some market participants may overreact or underreact to this new information. This is also consistent with the EMH as long as the reactions are statistically random such that no market participants can reliably employ this information to make an abnormal profit. Thus, any or all participants can be mistaken about market conditions, but the market as a whole is always right, and therefore market assets, including commodity assets such as crude oil, are priced appropriately at some equilibrium level.

Within this, convention now states that there are three subforms of the EMH—weak-form efficiency, semi-strong-form efficiency and strong-form efficiency—each of which subsumes weaker forms and has different implications for how markets behave. Weak-form efficiency states participants cannot earn excess returns using strategies employing historical market information, including past prices, volume and price volatility. Accordingly, current market prices fully incorporate all available historical information. Semi-strong form efficiency argues prices adjust within an arbitrarily small but finite amount of time and in an unbiased fashion to publicly available new information, so there are no excess returns from market behavior trading on that information, but excess returns are available for trading based on non-historical information. Consequently, market prices include all currently available public information. Lastly, strong-form efficiency asserts that prices reflect all information and excess returns are unavailable to anyone. Conventionally, this is that market prices incorporate all publicly and privately held information, including insider information.

Clearly, the concept of market efficiency has important implications for crude oil markets and their participants. First, market efficiency is associated with appropriate equilibrium spot prices. Second, the level of market efficiency thought to exist will determine the trading and other strategies of market participants. Third, where prices are set in markets that are inefficient, profitable (risk-adjusted) opportunities may be available. Finally, and drawing on the discussion in the previous section, if futures markets are efficient, hedging efficacy is enhanced. This is because if futures prices reflect all available information, then they provide the best forecast of spot prices. Thus, hedgers do not underpay or overpay for the service of risk transfer.

Consider first tests of weak-form efficiency in crude oil spot markets. Elsewhere, these typically range from single tests of the autocorrelation of price changes and unit root tests to establish a random walk to more sophisticated single and multiple variance ratio tests and cointegration analysis and error correction models. For the most part, these and other tests of weak-form market efficiency effectively condenses down to the degree of randomness in

historical price changes and the ability of lagged prices to forecast futures prices. As one example, Tabak and Cajueiro (2007) analyzed the efficiency of crude oil markets (Brent and WTI) by estimating the fractal structure of the time series, concluding that the crude oil spot market has become more efficient over time. Wang and Liu (2010) later extended this analysis (only to WTI) through observing the dynamics of local Hurst exponents based on multiscale detrended fluctuation analysis. The empirical results there showed that short-, medium- and long-term market behaviors in crude oil were generally exhibiting behavior that was more efficient over time. Further, small fluctuations in the WTI crude oil market were persistent. However, larger fluctuations had higher instability, both in the short- and long-term. In other work, Alvarez-Ramirez et al. (2010) studied the efficiency of crude oil markets using lagged detrended fluctuation analysis (DFA) to detect delay effects in price autocorrelations quantified in terms of a multiscaling Hurst exponent (i.e., autocorrelations are dependent of the time scale). The results, based on spot price data over the period 1986-2009, indicated important deviations from efficiency associated with lagged autocorrelations. Moreover, Alvarez-Ramirez et al. (2010) argued that any evidence found in favor of price reversion to a continuously evolving mean underscored the importance of adequately incorporating delay effects and multiscaling behavior in the modeling of crude oil price dynamics.

A common analysis in the finance discipline in relation to the weak-form efficient market hypothesis concerns tests of observed market anomalies, that is, specific and persistent instances of market inefficiency explained by observable fundamental or technical characteristics. In the only known study of an anomaly of this type in the crude oil market, Yu and Shih (2011) examined the presence of a calendar effect in the form of the weekend effect. In stock markets, this typically takes the form of higher returns (log or discrete price changes) on Fridays and lower returns on Mondays. Yu and Shih (2011) found using a probability distribution approach that oil markets exhibited instead a Thursday effect, with a shortening of the holding period from Wednesday to Friday and a leftward return distribution. Naturally enough, the authors concluded that this had some implications for risk management by participants trading in crude oil markets on a frequent or long-term basis.

A small number of additional studies also consider weak-form market efficiency in crude oil markets, but in crude oil futures markets. To start with, Lean et al. (2010) examined the market efficiency of crude oil spot and futures prices using both the mean-variance and stochastic dominance approaches. Using WTI crude oil data from 1989 to 2008, they found no evidence of any of the tested relationships, thereby inferring that there was no arbitrage opportunity between crude oil spot and futures markets, that investors are indifferent to investing spot or futures, and that the spot and futures crude oil markets were efficient and rational. In contrast, Wang and Yang (2010) used high-frequency (intraday) data on crude oil (along with heating oil, gasoline, and natural gas) futures markets to find some evidence for weak-form market inefficiency, but only in heating oil and natural gas, not crude oil. Lastly, Kawamoto and Hamori (2011) considered the weak-form market efficiency in crude oil futures markets but with futures of different maturities. WTI futures were yet again employed, though with cointegration analysis and error correction models. The results showed that WTI futures were consistently efficient within an 8-month maturity range and consistently efficient and unbiased within a 2-month maturity range.

Unlike analyses of market efficiency in many other commodity markets, very few concern high-order measures of market efficiency, namely the semi-strong and strong forms. In the only known recent study of semi-strong form market efficiency in crude oil markets, Demirer and Kutan 2010 examined the informational efficiency of crude oil spot and futures markets with respect to OPEC conference and US Strategic Petroleum Reserve (SPR) announcements and an event study methodology to detect abnormal returns between 1983 and 2008. Typically, event studies examine the statistical significance of particular information releases or market actions on price changes, with the expectation that in efficient markets, any new information should be quickly and accurately incorporated in current prices. For example, long delays in the incorporation of new information in prices may be reflective of informational or behavioral limitations in at least some market participants. The results indicated that only OPEC production cut announcements yield a statistically significant long-term impact with SPR announcement invoking a short-term market reaction following the announcement date.

Fundamentally, tests of semi-strong and strong form market efficiency in crude oil markets, both spot and futures, remain problematic. One problem concerns the identification of a fundamental equilibrium or benchmark-pricing model against which we can gauge price change as being efficient or inefficient. With strong form market efficiency, the more serious problem is the identification of trading behavior by market specialists and government and corporate insiders using superior pricing models and/or information to trade in crude oil markets. Nonetheless, the consensus in most crude oil markets, especially futures, is that market efficiency prevails in the long run, but that in the short run transitory and moderate inefficiencies may arise.

5. Crude oil as a financial pricing factor

Since the development of the Sharpe and Lintner capital asset pricing model (CAPM) in the 1960s, numerous studies have attempted to identify the determinants of security prices and correspondingly their returns. While both Sharpe and Lintner separately proposed that the pricing of assets only accords to their covariance with a market portfolio, they did not explicitly acknowledge other factors, such as the macroeconomy, in the pricing relationship. The subsequent development of Ross's arbitrage pricing theory and other multifactor models provided an opportunity to incorporate such factors. With this multifactor specification in mind, numerous studies, have sought to investigate whether individual macroeconomic variables constitute a source of systematic asset price risk at the aggregate market and industry level.

Crude oil is, of course, one key macroeconomic factor of obvious empirical interest. While it may be reasonable to expect that oil price changes influence stock markets, determining whether oil prices constitute a source of systematic asset price risk is difficult to ascertain and hindered by scant research. As Hammoudeh et al. (2004 p. 428) note: "There has been a large volume of work investigating the links among international financial markets, and some work has also been devoted to the relationships among petroleum spot and futures prices. In contrast, little work has been done on the relationship between oil spot/futures prices and stock indices, particularly the ones related to the oil industry". Similar sentiment is echoed in the earlier work of Sardorsky (1999, p. 450): "In sharp contrast to the volume of work investigating the link between oil price shocks and macroeconomic variables, there has

been relatively little work done on the relationship between oil price shocks and financial markets".

The rationale provided for the inclusion of oil prices in asset pricing models of typically stems from the importance of oil to the economy in question [see, for example, Hamao (1988) and Jones and Kaul (1996)]. Oil price changes have the potential to alter significantly future cash flows of firms through their influence on the costs of factor inputs (Faff and Brailsford, 1999). However, the significance of an oil price factor is potentially industry dependent. For instance, the transportation industry is highly vulnerable to oil price increases due to its heavy reliance on oil-based factor inputs, while the oil and gas industry is likely to benefit from such increases in oil prices [see, for example, Sadorsky (2001) and El-Sharif et al. (2005)]. Furthermore, Faff and Brailsford (1999) note that the detection of any indirect or direct impact of oil price changes on stock returns is complicated by the ability of individual firms to pass on rising factor costs to customers and by differing degrees of oil price hedging.

Additionally, identifying oil price effects is complicated by potential indirect relationships. For example, fluctuations in oil prices have the capability to indirectly influence stock price returns through its impact on inflation, and hence discount rates, and through its potential to dampen demand for goods (i.e. through its impact on discretionary spending). Obviously, knowing the extent of the impact of crude oil prices on financial assets like stock is of some practitioner interest. For instance, if an investor believes that the price of oil will surge above market expectations, then that investor could estimate an oil price factor to enable the construction of a portfolio that has the highest (positive) sensitivity to oil price increases. Likewise, the manager of a managed portfolio that is concerned with rising oil prices could construct their portfolio so that it has the lowest sensitivity to an oil factor.

For the early literature that does examine the significance of crude oil as a source of systematic asset price risk, the results have been inconsistent across studies and countries. Chen et al. (1986) and Hamao (1988) found no evidence of an oil price factor for the US and Japan, respectively. In contrast, Sardorsky (1999) and Kaneko and Lee (1995) conclude that oil prices are a significant factor in the US and Japan, respectively. However, of most promise are the early studies of Faff and Brailsford (1999), Sardorksy (2001), Hammoudeh et al. (2004) and El-Sharif et al. (2005) which attempted to examine the significance of an oil price factor at the industry level. These studies indicated that oil prices do constitute a source of systematic asset price risk and that the exposure to this risk varies across industries.

As just one example, Faff and Brailsford (1999) investigated the sensitivity of Australian industry equity returns to an oil price factor. Continuously compounded monthly returns over the period July 1983 through March 1996 are employed. Five of the twenty-four industries displayed a significant relationship with the price of oil. Industries with a significantly positive relationship with the price of oil included, as expected, the oil and gas and diversified resources industries. Those with a significantly negative relationship included paper and packaging, transport and banking. In a similar manner, Sadorsky (2001) sought to identify risk factors in the stock returns of Canadian oil and gas companies. Utilising an augmented market model [similar to Faff and Brailsford (1999)], Sadorsky (2001) regressed the excess monthly returns of the oil and gas stock index on the excess

return of the market portfolio and the oil price return. An exchange rate factor and a term premium factor were added to subsequent regressions. The results indicated a strong positive relationship with oil prices, the market portfolio, and an inverse relationship with the term premium and the exchange rate.

El-Sharif et al. (2005) provided a complementary analysis concerning U.K. data to that of Sadorsky (2001) (Canadian data) and Faff and Brailsford (1999) (Australian data). Daily data covering the period January 1989 to June 2001 was used. As with much of the previous research in this area, a multifactor model was employed to investigate the relationship between excess returns to the oil and gas sector and oil price returns, excess returns on the market portfolio, the exchange rate, and the term premium. Due to inter-temporal variability in the relationship between natural resource and equity prices [as highlighted in the work of Sadorsky (2001) and Faff and Brailsford (1999)], El-Sharif et al. (2005) divided the sample into twenty-five six-month periods, however, it is suggested that shorter sub-periods may yield superior results due to the increasing oil price instability. A consistently positive, and sometimes highly significant, relationship was found between oil prices and the excess stock returns of oil and gas companies. Four additional industries were tested (mining, transport, banking and software and computer services) with no significant relationship with oil price changes indicated. However, the significance of oil price changes on stock returns cannot be underestimated, with Huang et al (2005) concluding that oil price volatility explains stock returns better than changes in industrial output.

While the aforementioned studies concerned aggregate broad-based stock market indices, very few papers have attempted to relate conditional macroeconomic volatility to the conditional stock market volatility of a particular industry. In one such study, Sadorsky (2003) examines the determinants of US technology stock price volatility over the period July 1986 to December 2000. Utilizing both monthly and daily data, Sadorsky (2003) tests whether oil price volatility (WTI crude oil futures) and a series of other macroeconomic variables have any impact on technology stock price volatility (using the Pacific Stock Exchange Technology 100 Index as a surrogate). Conditional volatility was estimated using a generalization of a 12-month rolling standard deviation estimator, similar to that of ARCH estimates. The econometric results indicate, inter alia, a significant link between lagged conditional oil price volatility and conditional technology stock price volatility. However, industrial production and the consumer price index were found to have a larger impact on technology stock price volatility than oil. Hence, Sadorsky (2003) provides one of the few papers that attempts to investigate the association between conditional oil price volatility and stock price volatility.

A number of studies have since developed these approaches in a variety of contexts. In Australia, McSweeney and Worthington (2008) examined the impact of crude oil prices on Australian industry stock returns using multifactor static and dynamic models containing crude oil and other macroeconomic factors from January 1980 to August 2006. The macroeconomic factors used comprised the market portfolio, oil prices, exchange rates, and the term premium. The industries consist of banking, diversified financials, energy, insurance, media, property trusts, materials, retailing, and transportation. McSweeney and Worthington (2008) found crude oil prices are an important and persistent determinant of returns in the banking, energy, materials, retailing, and transportation industries. The findings also suggest oil price movements are persistent. Nonetheless, the proportion of

variation in excess returns explained by contemporaneous and lagged oil prices appeared to have declined during the sample period.

In the US, Odusami (2009) also reconsidered the impact of crude oil shocks on stock market, concluding a nonlinear effect. There was also some evidence of the impact of OPEC meetings, with the suggestion of prospective and important new information release, on US stock returns. Killian and Park (2009) also examined the role of crude oil shocks in the US, finding stronger, more significant and asymmetric impacts at the industry level to crude oil demand shocks than crude oil supply shocks. Importantly, Killian and Park (2009) also suggested that the impact of crude oil shock on stock markets was not so much through domestic cost or productivity shocks, rather through shifts in the final demand for goods and services, with some of the strongest responses outside the energy industry in transportation, consumer goods, and tourism services. Similar findings are echoed elsewhere in work on the effect of crude oil prices shocks on stock markets in Turkey (Eryiğit, 2009), Brazil, China, India and Russia (Ono, 2011), Greece, the US, the UK and Germany (Lake & Katrakilidis, 2009), Nigeria (Somoye et al., 2009), Gulf Cooperation Countries (GCC) (Arouri et al. 2010), Russia (Hayo and Kutan, 2005, Bhar & Nikolova 2010). Lastly, there is also evidence garnered from broader international studies (Nandha & Brooks, 2009; Jawadi et al., 2010) and from the experience of global industries, including oil companies (Sardorsky, 2008) and shipping (El-Masry et al. 2010). The literature includes a large number of similar applications (Chan et al., 2011; Ghoilpour, 2011; Hammoudeh & Choi, 2006; Hammoudeh et al., 2010; Nandha & Faff, 2006).

Overall, the evidence is now becoming increasingly consistent that crude oil markets exert a significant but varying impact on stock and other financial markets through the asset pricing mechanism. This effectively complements a broader and longer-established literature on the impact of macroeconomic activities on financial markets and the influence of crude oil on the aspects of the macroeconomy, including GDP, (un)employment and inflation. It is also clear that the impact of crude oil on asset pricing varies across industries, though the exact transmission mechanism through which this works is not especially clear and therefore demands further attention. Lastly, it is evident that the impact of crude oil markets on financial asset pricing and hence returns generally reflects its contribution to economic activity, with clear evidence of a long-term decline associated with the stage of economic development and efficiency gains and diversification in energy input markets.

6. Conclusion

This chapter reviewed the finance literature as it relates to physical (spot) and financial (futures and options on futures) markets in crude oil. As discussed, this builds on an older and more established economics literature in terms of the determinants of crude oil prices and the interrelationships between crude oil markets and the macroeconomy, particularly output, employment, and inflation. However, by its nature this literature also extends this general work with a focus on behavior in and between crude oil spot and derivative markets and between crude oil markets and those for financial securities. As argued here, for the most part, existing research on the finance dimensions of crude oil markets have focused on three core areas, namely, intertemporal price relationships in the physical and financial markets for crude oil, evidence on financial market efficiency in crude oil markets, and the role of crude oil as a pricing factor in asset pricing financial markets.

In terms of intertemporal relationships, there seems to be some empirical consensus from a relatively voluminous literature that crude oil futures markets exhibit the basic relationships expected in these markets. However, much remains unknown. For example, can we gather further insights on the risk management strategies of producers and users and the role futures and options can potentially play? Similarly, what impact do alternative energy spot and derivative markets have on those for crude oil and vice versa in a world increasingly characterized by energy substitution and diversification? In contrast, there is much less work on market efficiency concepts in the physical and financial crude oil markets. Moreover, most of this concerns weak-form efficiency and there is generally little attention given to tests of semi-strong or strong form efficiency, largely because of perceived difficulties in specifying equilibrium or benchmark pricing models and the limited availability of suitable data.

Finally, notwithstanding a sizeable and consistent literature on the role of crude oil as a pricing factor in financial markets, including both debt and equity, and seemingly despite efforts to expand this beyond aggregate market studies to those focusing on industries, much also remains to be done. For example, we know much less about the exact transmission mechanism through which changes in crude oil prices impact upon financial markets. Logic would dictate that this is through costs, such that industries and firms relatively more dependent on crude oil (and its processed forms) would be more affected. This would clearly explain crude oil as a pricing factor in, say, the transportation sector, but how exactly do we explain crude oil appearing as a priced factor in other sectors? It also remains a challenge to disentangle this direct effect from a more general indirect impact on consumer expenditure. Likewise, it also ignores the efforts by firms to hedge themselves prices increases in key factor inputs, like crude oil.

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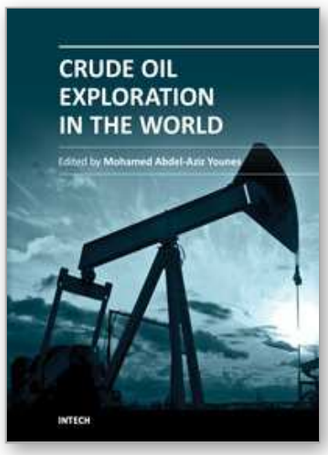
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