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Oil Price Drivers and Movements: The Challenge for Future Research

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1. Introduction

The complexity of the world oil market has increased dramatically in recent years and new approaches are needed to understand, model, and forecast oil prices today. In addition to the commencement of the financialization era in oil markets, there have been structural changes in the global oil market. Financial instruments are communicating information about future conditions much more rapidly than in the past. Prices from long and short-duration contracts have started moving more together. Abrupt changes in supply and demand, influenced by such events and trends as the financial crisis of 2008-09, uncertainty about China's economic growth rate, the Libyan uprising, the Iranian Nuclear standstill, and the Deepwater Horizon oil spill, change expectations and current prices. Although volatility appears greater over this period, financialization makes price discovery more robust. Most empirical economic studies suggest that fundamental factors shaped the expectations over 2004-08, although financial bubbles may have emerged just prior to and during the summer of 2008.

With increased price volatility, major exporters are considering ways to achieve more price stability to improve long-term production and consumption decisions. Managing excess capacity has historically been an important method for keeping world crude oil prices stable during periods of sharp supply or demand shifts. Building and maintaining excess capacity in current markets allows greater price stability when Asian economic growth accelerates suddenly or during periods of supply uncertainty in major oil producing regions. OPEC can contribute to price stability more easily when members agree on the best use of oil production capacity.

Important structural changes have emerged in the global oil market after major price increases. Partially motivated by governments' policies, major developments in energy and oil efficiencies occurred after the oil price increases of the early and the late 1970s, such as improvements in vehicle fuel efficiency, building codes, power grids, and energy systems. On the supply side, seismic imaging and horizontal drilling, as well as favorable tax regimes, expanded production capacity in countries outside OPEC. After the oil price increases of 2004-08, investments in oil sands, deep water, biofuels, and other non-conventional sources of energy accelerated. Recent improvements in shale gas production could well be transferred to oil-producing activities, resulting in expanded oil supplies in areas that were previously considered prohibitively expensive. The search for alternative transportation fuels continues with expanded research into compressed natural gas, biofuels, diesel made from natural gas, and electric vehicles.

In spite of these advances, some aspects of the world oil market are not well understood. Despite numerous attempts to model the behavior of OPEC and its members, there exists no credible, verifiable theory about the behavior of this 50 year-old organization. OPEC has not acted like a monolithic cartel, constraining supplies to raise prices. Empirical evidence suggests that at some times, members coordinate supply responses and at other times they compete with each other. Supply-restraint strategies include slower capacity expansions, as well as curtailed production from existing capacity. Regional political considerations and broader economic goals beyond oil are influential factors in a country's oil decisions. Furthermore, the economies and financial needs of OPEC members have changed dramatically since the 1970s and 1980s.

This review represents a broad survey of economic research and literature related to the structure and functioning of the world oil market. The theories and models of oil demand and supply reviewed here, although imperfect in many respects, offer a clear and well-defined perspective on the forces that are shaping the markets for crude oil and refined products. Much work remains to be done if we are to achieve a more complete understanding of these forces and the trends that lie ahead. The contents that follow represent an assessment of how far we have come and where we are headed. Around the world governments, busineses and consumers share a vital interest in the benefits that flow from an efficient, well-functioning oil market. It is hoped, therefore, that the discussion in this review will find a broad audience.

2. Price Volatility and Uncertain Conditions

Oil prices have fluctuated widely since 2004. Brent crude oil prices rose from $29 to $38 per barrel (annual averages) between 2003 and 2004. They rose steadily until 2008, reaching a record near $147 per barrel in July 2008. This price spike reflected extremely strong Asian economic growth, combined with certain geopolitical events. Prices collapsed below $33 within the next few months as the world economy spun downward into financial disarray. They spurted back to levels above $80 per barrel in 2010, as the economies in Asia and elsewhere recovered. Additional price increases in 2011 beyond $100 per barrel were prompted by continued Asian growth and supply uncertainty mounted with the Arab uprising and the Libyan disruption. Continued fears about the financial system and future economic growth lingered in August 2011, causing world oil prices to begin their retreat once again.

These conditions have created massive uncertainty about where future oil prices will be headed and what factors create these dramatic price movements. Peak oil arguments abound during an era when non-OPEC oil production has increased only modestly despite the record-high prices. Turmoil dominates the political landscape in the Middle East, fueling additional concerns about the security of oil supplies. Most disconcerting to both oil producing and oil-consuming nations has been the financialization of oil, where financial motives and trading permeate oil transactions and make physical markets appear less important.

This uncertainty creates very significant problems for major oil-consuming countries that are trying to recover from financial disintegration, as well as investors who are considering long-term allocations to commodities. It also raises important concerns for major oil-producing countries with ample resources. Should they expand capacity to supply growing economies and at what rate? How much spare oil capacity should be maintained to offset sudden oil-market surprises—unexpectedly higher economic growth, political unrest in oil-producing regions, or major oil spills in offshore drilling areas? Fundamental factors should be important for both capacity decisions, but these uncertainties have eroded the belief that these factors still operate in the same way that they have in the past.

Capacity expansion influences both short and long-term market operations. First, greater capacity allows more future production to meet growing demand. These decisions require an understanding of long-term market conditions. Second, additional capacity can also build surplus capacity for market imbalances. These decisions require an understanding of short-term market conditions. Although the distinction between the short and long term can be ambiguous, we define the short-term to include horizons of three years or less.

Oil markets are not easy to understand and projections of future oil prices have not been accurate consistently. If fundamental supply and demand analysis and oil market modeling have any benefits, it would appear to be in their ability to organize complex information efficiently and to provide better understanding of how oil markets perform. For this reason, it is sensible to emphasize these characteristics, rather than to focus on their suitability for forecasting.

3. Long-Run Oil Price Drivers and Models

Oil represents a substantial proportion of global energy demand. As the world's most highly traded international commodity, oil will continue to play a large role in meeting energy demand in the future. Over the long run, the price of oil will be influenced by four major trends: (1) global economic growth, (2) demand-side technological progress and efficiency gains, (3) new alternative energy sources, and (4) the changing costs of production. The depletion of easily extracted resources is pushing production into more technologically demanding fields, lower-quality crudes, and higher-cost operating environments. At the same time, dramatic improvements in technology are expected to continue to reduce the cost of finding and producing oil from such reserves. Government policies will have important impacts on the costs of both petroleum products and competitive energy sources. Understanding how production, consumption, and the price of oil will change over the coming decades is of vital interest to both oil-producing and oil-consuming nations, with strong implications for energy policy, economic growth, climate-change policy, and international stability.

3.1. Oil Demand: Drivers and Trends

Generally speaking, when the world economy as a whole experiences growth, oil demand will increase. The existence of this fundamental relationship is uncontested, but its strength varies between regions and will be moderated by many factors with the potential to curb demand, such as fuel-saving technologies, fuel-switching to different forms of primary energy, and policies designed to constrain carbon dioxide emissions.

Much of the recent growth in global oil consumption (which rose by 1.5% per year between 1985 and 2008) occurred outside the OECD nations. As a percent of world consumption, the emerging nations' share has grown from 37.6% to 44.5% over this period. Developing economies are expected to continue being the primary drivers of the growth in global oil demand. The hypothesized energy and environmental Kuznets curve, which views investments in energy efficiency as a luxury good that become more affordable and widespread as developing economies mature and prosper, teaches us that continued strong economic growth in China and elsewhere may work paradoxically to restrain the growth rate of demand—if only in the longer run.

3.1.1. Growth and Industrialization

Per-capita oil demand grows at the same rate as the economy in many emerging economies, so long as other factors like prices do not change. Many countries are experiencing rapid increases in vehicle penetration and ownership rates as incomes rise. Based on estimates as of 1973, oil income elasticities exceeded unity throughout the developing regions of the world, and approached a level of 2 in the poorest nations. This implies that oil demand should increase at least as fast as GDP in the developing world, holding constant energy prices and technological progress. In the poorest Asian nations, oil demand should expand nearly twice as fast as GDP (Medlock and Soligo 2001 and Van Benthem and Romani 2009).

In contrast, per-capita oil demand grows more slowly than GDP within the OECD, even before the impact of potentially rising prices is factored in. Vehicle ownership per person has stabilized and consumers are beginning to purchase alternative-fuel vehicles in these countries. Gately and Huntington (2002) estimate that the long-run income elasticity to be 0.55 in the more mature OECD countries, implying that oil demand may increase only about half as fast as GDP in the industrialized portions of the world (again, abstracting from the impact of potential changes in prices, regulation, and technology).

3.1.2. Oil Demand and Technical Progress

Whereas pure price-substitution implies reversibility, technological progress that is induced by price increases creates an irreversible and unidirectional effect that is not easily unwound, even when prices return to previous levels. Several distinct processes drive technical changes that influence oil demand. The first is exogenous change that is largely unrelated to specific changes in the price of oil or economic conditions. For example, airplane designs incorporated significant improvements in fuel efficiency, even prior to the price shocks of the 1970s. In an endogenous process, rising oil prices are the specific incentive that drives technical change. Automobile companies, for example, revamped their vehicle fleets after the 1970s to make passenger cars more fuel efficient; even when oil prices declined after 1985, those design innovations were never eliminated.

3.1.3. Alternative Vehicles and Competitive Fuels

Limited historical evidence exists by which to measure the strength and potential of inter-fuel substitution among competing fuels. In many countries, petroleum-based fuels appear to have no strong or viable competitor for powering transportation. That may be changing as countries have begun to make commitments to vehicles fueled by compressed natural gas, biofuels, and electrification. Additionally, companies may increasingly pursue gas-to-liquid processes as a technological option that substitutes relatively inexpensive natural gas for oil in the production of diesel fuels. Energy security and climate mitigation policies may accelerate these oil-reduction trends.

3.1.4. Demand Response to Oil Prices

If future oil supplies are expected to be scarcer than today, future oil prices will rise and curb some of the growth in demand; but, by how much? This question has probably attracted more of the attention of energy economists and commodity investors than any other issue during the last few decades. A major conclusion consistent with the findings of most studies is that the longer-run demand response to any gasoline price increases occurring over the next twenty years is likely to be several times larger than the short-term response that is initially apparent (Dahl and Sterner 1991 and Goodwin, Dargay et al. 2004). The response of consumption to price is the combined effect of many different decisions. Utilization decisions impact the gasoline market by reducing traffic activity and the number of miles driven by households. Over a longer period, household response to higher prices is also magnified as the vehicle fleet is retired and replaced.

The price elasticity of oil demand seems to be declining lately within the United States and perhaps more broadly within the OECD. Many countries outside of the OECD maintain large fuel subsidies that impose a wedge between crude and product prices (Arze del Granado et al. 2010). Removal of those subsidies, which have become quite expensive to maintain, would increase fuel prices to the end-user and thereby reduce future oil demand. The lack of data and estimates for the emerging countries limits our ability to foresee how these changes will influence oil markets in greater detail.

3.2. Oil Supply Availability and Costs

Despite significant gains achieved via enhanced oil recovery technologies, conventional oil supplies are diminishing in many fields located outside of the Middle East. Development of unconventional resources to offset this decline will be very important, but the cost, availability, and scale of resources such as Alberta's oil sands are as yet unknown. At the same time, oil supply prospects, even from conventional resources, may improve in certain areas. New oil may be discovered in relatively unexplored regions and reserve appreciation in known resource basins remains an important source of new additions. Technical progress will probably continue to reduce exploration and development costs significantly, as well as to enhance the safety and security of operations that extend further into frontier areas. Governments may reduce oil supply barriers by rolling back production royalties and taxes, and by easing constraints on leasing and acreage.

3.2.1. Resources and Geological Availability

Oil resources are scattered across the globe in formations with very different characteristics. Based upon its world oil assessment of 2000, the United States Geological Survey (2003) estimated that there were 1,898 billion barrels of remaining conventional oil and natural gas liquids, excluding cumulative volumes that had already been produced. These geological estimates are based upon likely discoveries, given the prevailing oil prices and available technologies present in 2000.

These conventional resources are supplemented by considerably larger volumes of unconventional resources—heavy oil, oil sands, and oil shale—that require specialized extraction technologies and significant processing before the oil can be sold. Aguilera et al. (2009) estimate that the combined volume of conventional and unconventional oil would last for 132 years if production increased by 2% per year.

3.2.2. Resource Costs

For economists evaluating market conditions, resource costs, rather than total reserves, determine whether scarcity prevails. Many geological estimates do not distinguish between resources that are inexpensive to extract and those that are much more costly to develop and produce. To fill this gap, a useful concept is the resource availability curve—a schedule that represents the total known resource base that could be developed at each successively higher-cost level.

Aguilera et al. (2009) derive an availability curve for conventional and unconventional petroleum resources. They estimate 7 TBOE (trillion barrels of oil equivalent) of conventional resources and 4 TBOE of heavy oil, 5 TBOE of oil sands, and 14 TBOE of oil shale with average production costs usually considerably higher than the comparable costs for conventional oil. The cost estimates for these unconventional petroleum resources are very uncertain and subject to change. To be useful, any long-run cost estimates should reflect production expanded to scale and the considerable learning that will accumulate through experience in developing these resources. Oil prices may well overshoot these long-run cost estimates during intervening years when additional unconventional sources are not yet large enough to meet growing demand.

3.2.3. Oil Supply from Competitive Regions

Producers outside the major exporting countries are generally considered as competitive price takers. Market prices must cover the marginal cost of producing the last unit of these supplies, including both the direct expenses and the firms' opportunity cost of drilling for oil, rather than engaging in another economic activity. If resource depletion is a factor, each supplier will also consider the opportunity cost of current extraction relative to future production. At higher prices, firms can justify exploring for and extracting more costly resources, and doing so earlier rather than later.

Two major trends are driving oil supply from regions outside of OPEC: the depletion of reserves that are easy to extract and the improvement of oil exploration and production technologies. The combined effects have led to an increase in mega-projects aimed at resources that were formerly inaccessible, either commercially or technically. Such projects include the Alberta oil sands, the deep water resources of the Gulf of Mexico, and the pre-salt deposits offshore of Brazil.

3.3. OPEC

The major oil exporters are sufficiently large to influence as well as to respond to price. They have market power. However, the extent to which market power has been exercised is less certain. The previous empirical literature leaves many questions regarding the impact of decisions and actions taken by OPEC. The data tends to support multiple competing theories, without definitively excluding any particular behavioral model. Analysts choose their favorite hybrid; they seldom test all versions. There is clearly room for additional research on the nature of OPEC and its evolution.

3.4. Long-term Models

The long-run behavior of the oil market has received considerable study through the application of computer models. Models can be classified by many different criteria, but we find it helpful to distinguish structural models from computational models. Both approaches take fundamental microeconomic theories about the objectives, constraints, and behaviors of market actors into consideration at their core. These theories are distilled into a mathematical structure, allowing for interaction between the actors within a specific market context. The primary distinction between the two categories is the level of complexity and detail; computational models have significantly more detailed representations of the market at the cost of model run time. They also have increased data requirements and may offer less straightforward interpretations.

Research into the formal modeling of the oil market began largely as a response to the oil crisis of 1973. The initial goal was to understand the role of OPEC decision making and its impact on the market price. Since that time, as the oil market has changed, and the research community has become more international, structural models have been applied in analyzing a wide range of issues involving oil. The major structural approaches include simulation, optimization, and game-theoretic frameworks.

In simulation models, the behavior of actors in the market is represented by a specific function contingent on market conditions. This function can be based either on some rule-of-thumb (such as a target price or target capacity utilization rule), or on historical econometric estimates of past behavior. Depending on the researcher's focus, the behavior of different agents may be described in various levels of detail. In general, OPEC is given more complex behavior, while non-OPEC producers follow a simple supply curve, often one that exhibits constant price elasticity. Of course, the researcher's goal is to develop rules or functions that are descriptive of actual behavior.

In an optimization model, at least one agent actively chooses its behavior to maximize an objective function, typically related to profit or welfare. For models of the oil market, the optimizing agent is generally assumed to be OPEC, or some subset of that organization. OPEC chooses a level of production to maximize the present value of profits, while taking how the resulting price will influence the decisions of competitive producers and consumers into account. While some models may have sophisticated representations of the limits to the knowledge available to the optimizing agent, in many cases, the optimizer is given complete foresight of the future path of the market. With the optimization approach, the researcher seeks to understand what a market player must do to obtain his best outcome.

In game-theoretic models, two or more agents are assumed to have market power, or at least some influence on each other's welfare. They attempt to take actions that are optimal, given their anticipation of what the other agent will do. Each agent is also assumed to take into account the strategic behavior of other actors in the market. A game-theoretic approach may be useful when it is necessary to explicitly consider the consequences of rivalry and competition between different large players in the market—for instance, when evaluating the incentives for individual OPEC members to deviate from established production quotas.

Computational models share many attributes with structural models and are largely distinguished by the sheer number of details included. The complexity of the models makes them costly to build and maintain and the level of detail makes it difficult to establish the impact of any one model choice. However, computational models facilitate certain types of analysis that are impossible with a structural model: detailed impacts upon individual stakeholders, specific technological scenarios, and full policy analysis. Moreover, one approach to computational modeling, so-called computable general equilibrium models, has been used extensively to investigate fuel substitution opportunities and the broader energy sector impacts of global greenhouse-gas emissions policies. Computational models also facilitate the division of labor in the modeling effort by dividing the project into distinct sub-modules.

Due to their cost and complexity, computational models are relatively scarce, but with cheaper computer power, they are becoming more common. Still, computational models are typically confined to institutions such as the International Energy Agency and the Energy Information Administration.

3.5. Research Gaps in Long-term Oil Markets

While there has been significant effort representing the long-term behavior of oil markets using models of all sorts, a great deal of work remains to be done. As new technologies are developed, demand grows, new kinds of resources are exploited, and relationships in the market change; the theories and models we apply to the oil market need constant re-evaluation. A few topics stand out as significant open questions in our understanding of the long-term behavior of the market going forward: demand behavior, modern OPEC behavior, producer welfare, and resource depletion.

3.5.1. Demand Behavior

With the exception of the large computational models, most oil models do not have a very sophisticated or detailed representation of the demand side of the market. Understanding demand dynamics would be useful not only in explaining recent price movements, but also in exploring the impacts this degree of demand variation has on oil-producing nations. Marked variation, but especially unpredictability, of demand presumably affects the welfare of producers, not just consumers, and may change the nature of their capacity investment decisions. Three major topics in demand behavior stand out as top candidates for further exploration: (1) the high rate of demand growth in developing countries, (2) the asymmetric response of oil demand to price changes, and (3) the role of technology in altering the energy intensity of oil-consuming activities.

3.5.2. Security and Climate Policy

Closely aligned with demand issues is the inclusion of other energy market dynamics that produce viable substitutes for oil-based products for transportation. Governments are adopting policies to accelerate the shift consumption away from oil through mandates, taxes, and subsidies—all in response to concerns about energy security and global climate change. To derive meaningful results, the broadening range of available substitutes for petroleum-based fuels requires the simultaneous evaluation of multiple fuel markets, rather than oil-only analysis.

3.5.3. Modern OPEC Behavior

In the late 1970s, OPEC was modeled by many to be a monopolist in the world oil market. One author once referred to it as a 'clumsy" cartel (Adelman 1980). Models developed in late 1970s and early 1980s examined a number of different theories regarding OPEC's behavior and market power. However, OPEC and its members have evolved through time and observations gleaned from the 1970s are now outdated.

In the most recent two decades, the global view of OPEC has changed. OPEC is no longer considered definitively as a cartel that exercises market power by regulating output. Smith (2009) suggests that OPEC has been restraining investment in new oil production capacity in recent years and thereby has contributed to higher prices in a market with very rapid demand growth. Although research efforts to study OPEC's behavior either econometrically or theoretically have diminished compared to prior years, there remains a need for new theoretical models describing OPEC; these models should be tested with detailed data culled from recent years.

3.5.4. Producer Welfare

Many of the market-power models treat OPEC production decisions as if they were made by a profit-maximizing firm or cartel. When trying to understand the impact of OPEC production decisions on global oil prices and consuming nations, such a formulation may be an adequate approximation of the decisions made by the organization. However, in reality, as sovereign nations, both political and economic concerns drive decision making. Oil-producing nations may constrain prices in order to maintain favorable relationships with other nations, or they may sell oil at a discount in their home market to benefit domestic consumers. It may make more sense to view the nations as maximizing welfare rather than maximizing profit.

Unfortunately, when moving from models that consider profit to ones that try to measure welfare, modeling techniques increase in complexity and require greater information on the national economy as a whole. While some models (De Santis 2003) have previously approached this important question, a great deal of work remains to be done in this area.

3.5.5. Resource Depletion

Oil reserves are finite and production will become more expensive and perhaps eventually hit a peak (Hubbert 1962). It remains unclear when such a peak will occur and whether it will be based on a lack of available resources or the lack of sustained crude oil demand. In fact, the threat of peak oil has loomed over the horizon since the dawn of the petroleum age, but consistent resource discoveries, unconventional resources, and technological breakthroughs have so far managed to expand oil supplies and may continue to mitigate crude resource scarcity for the foreseeable future. As discussed elsewhere (Smith 2012), it is not even clear that a peak in the production of oil, if it does occur, would be a harbinger of impending scarcity.

4. Short-Run Oil Price Drivers and Models

Generally speaking, conclusions regarding the short-run behavior of oil prices are even less certain than our knowledge of the factors that drive long-term trends. In large part, this is due to the relatively short history of investigation into short-run fluctuations, as well as recent changes in the composition and liquidity of short-term oil markets that have only begun to be sorted out.

Modeling short-run changes in the oil market requires different techniques, depending upon the specific issue under investigation. Financialization, in particular, has made the oil futures and other derivatives market more liquid and perhaps more influential, while the number of participants in financial markets has increased because of hedging and investment opportunities. The use of high-frequency data may be required to consider all the relevant details in short-term models, but much of that data is not available in the public domain. The primary goal of short-term models is to provide a better understanding of short-term price movements and to create short-term forecasts. In contrast with long-term models, short-term models do not usually seek to determine what the future equilibrium path for oil prices will look like. Instead, they attempt to forecast prices or price changes that are expected to be observed in the near future. This is typically attempted with the help of reduced-form models that estimate parameters of statistical models that best describe short-run price movements without considering the fundamental forces of supply and demand. Short-term models also use the powerful financial theories concerning arbitrage and risk-taking in an attempt to infer market expectations from observed future prices.

4.1. Critical Observations

During the previous decade, the oil market experienced significant short-term upsets, one the most important of which was the boom-bust price cycle during 2008. That particular episode challenged the ability of conventional models to provide adequate explanations and forecasts of oil prices. Many studies have looked to find structural explanations, but there still is no consensus on the underlying economic causes. In addition to the high levels of price, a higher level of volatility has been observed in the oil market in recent years. For the first time, a change of $100 per barrel in only four months was observed in oil prices from July to November 2008.

These trends are not limited to the oil market; financial activity and turmoil in commodity markets in general have increased. The volume of investment in commodity index funds, overall futures market trading activity (as revealed by the open interest in all contract maturities), and correlations among commodity prices, as well as between commodities and equities, have increased by varying degrees. Forward curves have become substantially flatter at times, indicating that futures prices at varying maturity dates are now moving more closely with each other and also with spot prices. Financialization may act as a double-edge sword; it increases market liquidity and facilitates price discovery and risk management. However, it also creates more opportunities for some traders who would attempt to distort and manipulate futures prices.

Against this backdrop, there appear two overriding challenges for the modeling community. First, is the need to examine whether futures trading causes artificial movements in the spot price of oil or not, and, if so, to trace out the expected remedial effect of alternative regulatory reforms. Second, is to assess if and how financial variables can be used to forecast future price paths more accurately than methods that are based on fundamental analysis alone.

4.2. Fundamental Drivers

Certain economic factors have played a fundamental role in recent price changes. Supply and demand shocks, together with the continuous flow of news and uncertainty that surrounds them, are the primary drivers underlying short-run oil price dynamics. The impact of these shocks is magnified by the low elasticities of both short-run oil supply and demand. Hamilton (2009) demonstrates that under specific assumptions about the elasticities of supply and demand, one can explain the 2008 boom-bust price cycle just by using fundamental supply and demand factors. A caveat is that the price predictions drawn from such models are extremely sensitive to the specific magnitude of the presumed elasticities. Nevertheless, short-term supply and demand drivers are believed to be able to describe most of the observed price changes. This section reviews these fundamental drivers.

4.2.1. Short-term Supply Drivers

During 2005-08, available inventories were depleted while major oil-producing countries held low levels of spare capacity. Considering the inverse relationship between spare capacity and spot oil prices, and the inelastic supply in the short-term, this has led to higher price levels.

Short-term supply shocks have also influenced the oil market. The Deepwater Horizon oil spill in the Gulf of Mexico and the revolution in Libya are two recent examples of such events. Consider first the deep water Horizon spill. The methods of obtaining liquid fuels are becoming increasingly reliant on advanced and capital intensive technologies. From deep water drilling, to the processing of oil sands, to advances in refining, the oil market is changing its risk profile. While engineers are constantly working to perfect control systems and reduce the chance of failures, the potential for damage from any single catastrophe is increasing. Furthermore, with the increasing lumpiness of production from the trend towards more complex megaprojects, the supply impact of a single outage (or addition) is increasing, potentially leading to greater price volatility (Skinner 2006).

4.2.2. Short-term Demand Drivers

The short-run demand for oil is also relatively price inelastic. There are four main reasons for this. First, oil consumption levels cannot change quickly, due to the existing stock of vehicles and other equipment that uses oil. Second, in the OECD countries, oil consumption is less responsive to price changes because the share of consumers' energy expenditures as a fraction of their total incomes is relatively low. Third, oil demand in developing countries is largely driven by steady income growth and industrialization. Fourth, the demand impacts of crude oil price changes are in many cases offset by government subsidies or taxes.

Macroeconomic news also influences oil prices. As incomes increase and economies expand, more energy will be used for transportation, heating, and cooling. Hicks and Kilian (2009) utilize a direct measure of global demand shocks based on revisions of professional forecasts of real GDP growth. They show that recent forecast surprises are associated primarily with unexpected growth in emerging economies. According to this line of research, markets have been repeatedly surprised by the strength of this growth.

Finally, U.S. foreign exchange and interest rates exert an influence on the price of oil. The price of oil (in USD) increased by more than 600% from January 2002 to July 2008. The same increase in terms of the Euro was less than 300% as the Euro gained strength during that interval. As this example suggests, depreciation of the U.S. currency may either lead or at least contribute to an increase in oil prices (which are typically expressed in U.S. dollars). Fluctuations in interest rates influence the value of oil in the future relative to its value today, which can lead to changes in production, consumption, and storage decisions. In addition, changes in interest rates prompt changes in the prices of financial derivatives accordingly.

4.2.3. News and Information Signals

In financial markets, the price is believed to reflect all publicly available information. Newly released information about future events will have a proportionate impact on today's price. All kinds of news are relevant: information regarding the economic growth of different countries, the prices of other commodities, currency rates, major countries' stock market movements, signs of geopolitical unrest or uprisings, unexpected severe weather conditions and natural catastrophes, and many other factors. The flow of information can change prices frequently and sharply. However, to have any impact, the news must be credible.

Previous research shows that not all announcements made by major players in the oil market (OPEC, IEA, etc.) are credible. To better understand short-run price movements, it is important to distinguish between relevant, credible announcements and ones that are ignored by the market. An important step in conducting this analysis is to consider the incentives of the issuers of information: specifically, whether those objectives are aligned with the truthful revelation of information. A signaling framework and a forecast model can be used to simulate the effect of new announcements and analyze their incentives.

4.3. Price Forecasting Approaches

Most short-term oil market models focus exclusively on oil price and its statistical time series properties. In contrast, structural models explicitly specify and attempt to estimate the impact of changes in oil demand and/or supply. This distinction means that short-term price models are mainly limited to the task of forecasting, rather than providing economic interpretation of the sort required for policy analysis. Despite the rather large number of recent short-term price models that have appeared in the literature, significant opportunities remain for further study.

4.3.1. Reduced Form Models

Reduced form models take advantage of financial and structural data and employ econometric tools to build a model and estimate its parameters. These models are usually applied to forecast a specific variable (e.g., world oil price). They differ primarily in terms of the complexity of the statistical structure that is assumed to fit the data. Three contrasting approaches have been used to study oil price data: 1) time-series analysis, e.g. autoregressive moving average (ARMA), general autoregressive conditional hetereoskedastic (GARCH), 2) Structural Vector Autoregression (SVAR) and 3) non-parametric regression, e.g. artificial neural network (ANN) (Jammazi and Aloui, 2012). Each approach has its own advantages and, at the conceptual level, no one approach is superior to the others. Therefore, the choice among the models should be dictated by the observed statistical properties of the time series involved in the analysis.

If the reduced form models are applied for purposes beyond simple forecasting, however, serious problems arise. These problems center on the concept and interpretation of "causality," a term that plays an often misunderstood role in many short-run time-series analyses. Causality is, of course, central to the study of policy analysis. To be successful, policy makers must be able to anticipate the consequences of their actions. Will trading limits cause volatility to decrease? Will producing from the strategic petroleum reserve cause prices to decline? And so on. The cause and effect relationships that are implicit in these questions represent something stronger than the statistical tendency of two variables to move together, which is not evidence that an exogenous change in one variable will cause another resulting change in the other variable. Therefore, it is essential when contemplating short-term forecasting models to understand that a finding of "Granger–causality," which is based on patterns of correlation, neither proves nor disproves that a fundamental causal relationship links one variable to another. To the extent that a fundamental structure is added to the short-term approach in the form of a SVAR, it is also important to keep in mind that the structure that is assumed to link the variables in a causal chain is typically dictated by convenience, as when a diagonal pattern of variable exclusions is adopted in order to permit the model to be solved recursively; or, when a priori constraints are imposed on the size of key parameters to achieve identification of causal relations. Of course, if the constraints are untested and inappropriate, so may be the causal relations.

In summary, short-term statistical models will continue to flourish, based in part on the availability of additional high-frequency pricing data and in part due to increased scrutiny of financial investors in the oil market. It will be imperative for both the producers and consumers of this research to keep in mind the fundamental limitations of these time-series methods and to tailor their inquiries to questions that can properly be answered with the tools at hand.

4.3.2. Financial Models

Financial models are a more recent brand of oil price models that extend statistical analysis to some of the newer time series (futures prices and options) with guidance from relevant hypotheses developed in the theory of finance. Since options and futures contracts convey information about the future, they have been considered as a first step in incorporating financial data in oil models. However, futures prices may include a risk premium that varies through time, and therefore, they do not represent a simple expectation about the price that will prevail in the future. It has been shown, for example, that "no change" forecasts are more accurate than forecasts based on futures prices (Alquist, Kilian et al. 2010).

Pagano and Pisani (2009) document significant time-variation in the risk premium and use the degree of capacity utilization in U.S. manufacturing and oil inventory levels as proxies for this variation. They demonstrate how one can find expected future prices based on the combination of futures prices and the risk premium. Thus, if one could model and forecast the risk premium when combined with market data, it should be possible to obtain estimates of future expected prices. Given the potential value of this ability to producers and consumers alike, further research into determinants of the risk premium seems warranted.

4.3.3. Structural/Financial Hybrid Models

Hybrid models, combinations of structural and financial models, are motivated by the need to produce short-term forecasts that are more consistent with supply and demand frameworks. These models are calibrated to base-case forecasts of a long-term model, with outcomes that are adjusted based on the flow of new market information and short-term economic responses. Relevant new market information would include price observations from futures markets, forecasts in demand growth, and supply shocks (e.g., the reduction in Libya's production during 2011). Hybrid modeling requires estimates of both short-term and long-term elasticities with which to simulate price responses. The model takes information signals as input and generates price and quantity paths as output. In light of the Efficient Market Hypothesis, the market responds instantly to the new forthcoming information. Further efforts to incorporate theories of commodities and storage might lead to models capable of forecasting inventory changes and the movement of futures prices as well. (e.g., Routledge, Seppi, and Spatt 2000).

4.3.4. Modeling Volatility

Market price volatility can be estimated either from backward-looking historical data or from forward-looking financial derivatives using implied volatility (Szakmary et al. 2003). Indeed, even for models where volatility is not of direct concern, a researcher might need to know how volatility and price shocks lead to changes by consumers and producers. For example, the use and production of oil are heavily tied to existing capital stock and capacity investments. Price shocks, even over a relatively short time frame, can have lasting impacts on demand and supply for years to come through their impact on capital investment. Monte Carlo methods and artificial neural network technology could be applied to simulate supply and demand shocks and to estimate the benefits of major producers adopting strategies that stabilize prices, but that is all dependent on first developing an understanding of how the use of excess capacity and stockpiles influences volatility.

4.4. Analytical/Theoretical Models and Insights

Financial aspects of oil markets are not well explored. Studies are still trying to confirm a range of theoretical hypotheses about the operation of the financial markets and to identify the most important financial drivers. These include models that do not try to simulate or forecast the whole oil market. Instead, they use partial equilibrium or econometric techniques in an attempt to understand short-term market movements more accurately and to distinguish among competing theoretical hypotheses.

During 2000-08, when oil prices were increasing, investments in commodities markets also increased significantly. This triggered the question of whether the price rise of 2008 represented a financial bubble of some kind or not. Brunnermeier (2009) defines a speculative bubble as characterized by the following elements: (1) prices are higher than the fundamental value, (2) a group of investors buys the asset based on the belief or sentiment that they can sell it to others later at a higher price, and (3) such beliefs or sentiments cannot be supported by fundamental factors.

Studies on the role of financialization can be categorized into two groups: conceptual models and statistical tests. The former type of analysis consists of deductive arguments for accepting or denying the hypothesis that an increase in financial activity will cause prices to rise more than what fundamental factors would dictate. The logical validity of these arguments rests solely on the underlying assumptions independent of any empirical evidence. The latter type of analysis focuses on quantitative relationships between trending variables to find statistical patterns of predictability.

A few studies cite conceptual arguments to advance the claim that excessive investment in commodity index funds might have played a role in creating the bubble. However, conceptual analysis alone cannot establish the strength or magnitude of the effect. Thus, additional empirical research is needed to clarify the picture. Certain conceptual relationships remaining so far are still rather inscrutable, even after they have been quantified. For example, Tang and Xiong (2010) find a link between increased price correlations among different commodities and the growing volume of commodity index investments. However, there is no indication, theoretical or otherwise, that higher correlations are good or bad.

In any event, elevated correlations are not evidence of a bubble. Regarding the possibility of a bubble induced by financialization, it is useful to remember that price movements in futures markets with rising index fund investment have not been moving uniformly upward (Irwin, Sanders et al. 2009). Moreover, Headey and Fan (2008) show that prices of many non-financial commodities—commodities that were not financialized—displayed similar dynamics as the financialized commodities, despite having no influx of speculative financial investors. There is considerable room for additional research into the price movements of all commodities, whether they are financialized or not. The parallel movements suggest the presence of some common factors beyond financialization and research is needed to identify and measure the influence of those factors. It seems likely that any progress in this direction will depend on a more complete appreciation of the role of common demand shocks, inventories, and convenience yields.

4.5. Statistical Tests

Researchers commonly perform statistical causality tests to describe the temporal relationship between speculators' trading activity, oil price movements, and volatility. As noted above, these tests using Granger causality establish causality not in a structural sense, but only confirm whether the observed movement in one variable precedes the changes observed in another variable. The difference is important: although one might move a picnic inside just before it starts raining, moving the picnic doesn't cause the rain. With that caveat in mind, and using non-public data, the Interagency Task Force on Commodity Markets (2008) studied the dynamic relation between daily price changes and changes in the positions of various categories of traders. They found that some trader positions can be predicted as a response to price changes, but not the reverse. Sanders and Irwin (2011) find evidence that larger long positions by index traders Granger-cause lower market volatility. This result is contrary to the popular belief that index traders' activities increase market volatility.

There is some additional evidence on the other side of the argument and the conflicting conclusions are an invitation to pursue further both conceptual and empirical research into the causes of commodity price movements. One example is the group of studies that evaluate whether or not statistical characteristics of oil price movements match the pattern of an explosive bubble. In contrast with explosive bubbles that prevailed for several months in the copper and nickel markets, Gilbert (2010) finds only weak evidence for an explosive bubble in the oil market, and that it appears to have endured for only a few days in July 2008. Even so, do we know what caused it, or why it subsided? Further, a few studies report some evidence, conceptual as well as empirical, that financial activities were driving the oil price away from its fundamental value during 2008. Although fundamental factors are important in his analysis, Einloth (2009) suggests that speculators may have been building inventories from March to July in 2008 based upon evidence that spot prices rose further after convenience yields had begun to fall. Singleton (2011) finds significant empirical support that investor flows influenced excess returns from holding oil future contracts of different maturities, after controlling for a number of other exogenous factors.

In summary, there have been many studies, but as yet no absolute consensus on the causes of the oil price boom and bust of 2008. Although there exists only limited statistical evidence that the price cycle represented a speculative bubble caused by an influx of financial traders, the matter remains the subject of great debate among researchers, policy makers, and the general public. The value of any further work that helps to clarify this issue would be substantial.

4.6. Prescriptive Models

Short-term modeling is a relatively new approach. Some studies have tried to build a theoretical framework for interactions between the financial markets and the physical markets. These prescriptive studies usually simplify the details of the actual market and examine various phenomena that would be expected to occur under certain conditions. The main goal of this deductive approach is to understand how the market works, rather than forecasting or simulating with high accuracy.

For example, Deaton and Laroque (1996) and Routledge, Seppi, and Spatt (2000) consider storage agents in the commodities' markets and determine how the levels of inventories should change with uncertainty and how forward curves should behave in such settings. Routledge, Seppi, and Spatt interpret the concept of convenience yield as an option that storage agents will exercise at an optimal time. Allaz (1992) develops a generic commodity market model (1992) to demonstrate that, depending on the relative strength of the hedging and strategic motives, a producer's optimal position in forward markets may be either short or long. Brandts, Pezanis-Christou, and Schram (2008) study of Cournot (quantity) competition and Liski and Montero's (2006) inquiry into a potential link between forward contracting and collusion are further examples. The stylized nature of modeling that lies behind all of these studies invites extensions that explore the robustness of the findings to more realistic depictions of the agents who trade in these markets.

5. The Role of Saudi Arabia in the Global Oil Market

The influence of Saudi Arabia on the global oil market is indisputable. Saudi Arabia's role and decision parameters since the discovery and production of oil in the Kingdom have been determined by different factors. Al-Moneef (2011) discussed this issue and highlighted four important factors.

The first factor is the size and production life of Saudi Arabia's oil reserves. For the past fifty years, Saudi Arabia has had very large crude oil reserves, equivalent to 20% of the world's proven reserves.

The second factor is the diversity of Saudi Arabia's export outlets. Saudi Arabia is exporting to the U.S., Europe, and the Far East. This diversity of outlets (and crude types exported) offers Saudi Arabia marketing flexibility and highlights the international consequences of its policies. In addition, Saudi Arabia is exporting its oil to the rest of the world from two domestic terminals located on its eastern and western coastlines.

The third aspect is the Kingdom's large crude oil production capacity. Saudi Arabia maintains a large excess capacity that is available to face supply disruptions and demand surges. Saudi Arabia's excess capacity in the past three decades since 1980 averaged 60% of OPEC's (and of the world's) excess production capacities, while its share in OPEC's and the world's production averaged 32% and 12% respectively during the period. This unused capacity averaged 35% of Saudi oil production during the 1982-1990 period, 13% during the 1990s, and 14% in this decade. OPEC's averages over these three periods were 17%, 6%, and 4%, respectively.

While the other OPEC members' excess capacities depend on market conditions, Saudi Arabia made an official policy since the mid-1990s, of maintaining 1.5-2 MBD excess oil production capacity at all times. Saudi Arabia's role has been very useful to soften the impact of major oil supply interruptions, such as the Iran-Iraq war, Iraq's invasion of Kuwait, the Venezuela crisis in 2003, Hurricane Katrina in 2005, and the Libyan crisis in 2011. These actions helped in lessening oil market volatility and stabilizing oil prices.
The fourth facet is the role of oil in Saudi Arabia's economy. For the past three decades, oil has represented 35% of Saudi Arabia's GDP, 84% of its government revenues, and 90% of its merchandise exports. These rates explain the high interdependence between the Kingdom's domestic and international oil policies.

These four factors have pushed Saudi Arabia to develop its own oil industry through its national oil company Saudi Aramco. The company was created through the purchase by Saudi Arabia of the assets of the four American companies operating in the Kingdom. Saudi Aramco was entrusted with the tasks of managing and developing the hydrocarbon resources of the Kingdom to achieve its development objectives, executing the government energy policies, and developing the technical skills needed in that sector.

Saudi Arabia's oil policies are geared towards efficiency and sustainability, which involves stable oil markets and an efficient oil industry that is able to play a strong role in the oil sector. In the face of environment uncertainties, Saudi Arabia is investing in research and development projects such as research centers, universities, and companies.

Regarding the role of Saudi Arabia in OPEC, it has been as important for OPEC as OPEC has been for Saudi Arabia (as suggested by R. Mabro, Oxford Institute for Energy Studies 2001). The roles of OPEC and Saudi Arabia have evolved in line with market changes. Such changes include the diversity of market players, the influence of the financial markets on the physical markets, the energy policies of consumer countries, and climate change, as well as energy security concerns.

Since the influence of the financial market on the physical oil market is increasing, Saudi Arabia has acknowledged the new market reality and adopted a policy of urging the international community to exert some regulatory oversight, as well as transparency measures, over the means of transactions in such markets. In order to stabilize the market, Saudi Arabia has been collaborating with international organizations such as OPEC and

IEA to reach better predictability. The Kingdom is also promoting the strengthening of the producer-consumer dialogue, among other things, by strengthening the role of the International Energy Forum (IEF), created in 2003 and entrusting it to coordinate the Joint Oil Data Initiative (JODI) to enhance the flow of timely and accurate oil data worldwide.

In the early 1990's, Saudi Arabia realized that the challenges of climate change would add to oil supply and demand uncertainties and so it integrated its climate-change policy with its oil policy. It also considers energy security as a two-dimensional concern: supply security (the availability, diversity, and reliability of energy supplies at all times) and demand security (the predictability, efficiency, and growth of energy demand in line with economic growth).

Saudi Arabia is expected to continue playing a dominant role in stabilizing the global oil market. The Kingdom will continue its efforts to ensure sustainable oil supply to the world with stabilized long-term prices at reasonable levels. At the same time, it will go on with its investments in the oil and gas sectors to ensure adequate supplies and sustainable economic growth. It is expected to maintain an excess capacity of 1.5 to 2 MBD to face supply crises efficiently. Finally, Saudi Arabia's oil policy will be defined in dialogue with other producers and consumers to address the environmental, investment, and price volatility challenges as a whole.

6. Conclusion

The complexity of the world oil market has increased dramatically in recent years and new approaches are needed to understand, model, and forecast oil prices today. In addition to the rapid financialization of the oil market, many fundamental structural changes have affected physical markets for oil. Financial instruments now communicate information about expected changes in the underlying fundamentals much more rapidly than in the past, so the implications of both financial and physical developments are clearly linked.

Casual evidence of the closer relation between financial and physical markets may be found everywhere. The prices of long- and short-dated contracts have started moving more closely together. Sudden supply and demand adjustments, including those related to China's economic growth, the Libyan uprising, and the Deepwater Horizon oil spill have changed expectations in ways that affect both current and futures prices. Although volatility appears to have increased, financialization has arguably made price discovery more robust and expectations more transparent. Most empirical economic studies suggest that expectations regarding fundamental drivers and their future trends shaped prices during the 2004-08 cycle, although over-exuberant expectations cannot be ruled out completely, based on available evidence.

With increased price volatility, major exporters are now considering ways to provide more price stability, which is needed to improve long-term production and consumption decisions. Managing excess capacity, primarily within OPEC, but also in the strategic stockpiles held by major consuming nations, has historically been an important factor in keeping world crude oil prices stable during periods of sharp demand and supply shifts. To what extent would the expansion of excess capacity alter market expectations in the current environment? Would the result be greater price stability in the face of uncertainties regarding, for example, the rate of Asian economic growth, the debt crisis in some European countries, the restoration of Libyan production, and heightened tensions between Iran and the West? OPEC can pursue price stabilization strategies more effectively if the causes and consequences of volatility are better understood and if OPEC members can coordinate on the use of additional oil production capacity.

Within the context of long-term oil price drivers, the role of Saudi Arabia in the energy market is quite important. Maintaining and expanding Saudi crude oil capacity, if undertaken, would provide a supply cushion to lessen oil price volatility. Unfortunately, one does not know the magnitude of these effects because there is uncertainty about the parameters influencing supply and demand behavior. History tells us that there have been periods when expansions in Saudi output stabilized oil prices, for example, in 1991 during the first Gulf War. It also reveals that there have been other periods when oil prices continued rising despite Saudi expansion, for example in 2008 leading up to the financial crisis.

In evaluating any decision regarding the use of excess capacity, it is important to know what other factors are moving oil prices at the same time. Another important aspect of Saudi Arabia's role in the oil market involves continued oil exploration efforts and the development of new fields that would allow production to keep pace with the growing global oil demand in the long run. Saudi Arabia's role also includes the maintenance of excess capacity that could be released immediately in periods when oil shortages suddenly emerge in the market.

Apart from the short-run consequences of price volatility, we must learn from the important structural changes that have occurred in oil markets after major price increases, because similar events are likely to happen again in the future. Partially motivated by government policies, the automobile industry dramatically improved vehicle fuel efficiency in the mid to late 1970s. Seismic imaging and horizontal drilling in the early 1980s expanded production capacity in countries outside OPEC. Recent improvements in shale gas technologies are now being extended to shale oil as well, resulting in expanded oil supplies in areas recently considered prohibitively expensive. The search for alternative transportation energy sources continues with expanded research into compressed natural gas, biofuels, diesel made from natural gas, and electric vehicles. Which of these factors, or others, will produce the next game-changing impact on the oil industry?

Many fundamental aspects of the world oil market remain unclear. After 40 years of research, there exists no credible, verifiable theory about the behavior and influence of OPEC. It is evident that OPEC members do not consistently act like a monolithic cartel. Empirical evidence suggests that at times members coordinate supply reductions and at other times they compete with each other. Output can be managed either by production in the short-term, or by limiting investment to expand capacity in the longer-term. Clearly, these are complementary strategies, but how can or should they be coordinated? Regional political considerations and broader economic goals beyond oil also must enter the calculations of each OPEC member country. These influences have also changed rapidly as the economies of OPEC members have been transformed dramatically during the past two decades; financial needs for exporting oil now weigh heavily in their decision-making and their actions continue to have a strong effect on the rest of the world.

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