J.P. MORGAN CENTER FOR COMMODITIES
UNIVERSITY OF COLORADO DENVER BUSINESS SCHOOL

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

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TABLE OF CONTENTS
Vol. 3, No. 1: Summer 2018

Introduction

The *Global Commodities Applied Research Digest (GCARD)* is produced by the J.P. Morgan Center for Commodities (JPMCC) at the University of Colorado Denver Business School. The University of Colorado Denver Business School is led by Dr. Rohan Christie-David, Ph.D., Dean and Professor of Finance. The JPMCC's Research Director is Dr. Jian Yang, Ph.D., CFA, who is also the J.P. Morgan Endowed Research Chair and Professor of Finance and Risk Management.

Research Director Report

Dr. Jian Yang, Ph.D., CFA provides an update on the JPMCC's research activities and future plans. Dr. Yang's three goals for the JPMCC are (1) for the center to become globally known for its innovative research in the commodity arena, (2) for the JPMCC to become a leading educator of cutting-edge knowledge in the commodities space, and (3) for the center to become a major participant in the exchange of knowledge amongst commodity thought leaders. Towards the latter goal, Dr. Yang is organizing the JPMCC's second international commodities symposium, which will take place in August 2018 and which will include many top commodities scholars.

Advisory Council

The JPMCC's Advisory Council consists of members of the business community who provide guidance and financial support for the activities of the JPMCC, including unique opportunities for students. Select Advisory Council members also contribute articles to the *GCARD*.

Research Council

The JPMCC is honored to have a distinguished Research Council that provides advice on shaping the research agenda of the Center. Amongst its articles, the *GCARD* draws from insightful presentations and discussions by the JPMCC's Research Council members.

Editorial Advisory Board

The *GCARD*'s international Editorial Advisory Board consists of experts from across all commodity segments, each of whom have an interest in disseminating thoughtful research on commodities to a wider audience.

Contributing Editor's Letter

The fifth issue of the *Global Commodities Applied Research Digest (GCARD)* draws from the JPMCC's varied expertise across academia and industry. The Summer 2018 issue includes a special focus on the JPMCC's inaugural international commodity symposium that took place in August 2017. The current issue also examines the prospects for commodities in light of geopolitical tensions and trade war concerns. In addition, the present edition examines various futures trading strategies, including momentum trading, positioning analysis, pairs trading, and volatility analysis. Finally, members of the *GCARD*'s Editorial Advisory Board have contributed articles on the fundamental developments in the crude oil market as well as on the considerations in evaluating renewable energy contracts. We welcome reader feedback on this issue!

Research Council Corner

The biggest current threat to global growth is a trade war. There are other risks. The U.S. Federal Reserve is unwinding quantitative easing and raising rates, but making the policy shifts very gradually with careful market guidance. Governments are focused on whether they need to cut taxes, not raise them, so there would be no growth risks from fiscal policy. Consumer confidence is relatively high around the world, from mature industrial countries to young emerging market countries. Equity market valuation may appear high to some, but stock market corrections do not cause recessions unless there is a financial panic – and systematic risks from financial institutions are much lower than when the last crisis occurred in 2008. After considering the other risks, we stand by our analysis that if the current synchronized global economic expansion is derailed, the most likely cause will be a trade war. Yet, we are optimistic. So far, the actions taken earn only the terminology of "Skirmishes," but if they escalate to "Battles" and then a "Trade War," we will need to reassess the risks. This article provides a review of the issues and challenges of trade protectionism.

Renewable power purchase agreements (PPAs) have long been important enablers of renewable energy development. They are a means to providing the revenue certainty that project developers need to secure financing for capital-intensive wind and solar projects, and they also give renewable energy buyers access to the renewable energy they desire without upfront capital outlay or the need for development expertise. However, these

(Continued on next page.)

Research Council Corner (Continued)

Reports on Research Council Meetings

(Continued on next page.)

Reports on Research Council Meetings
(Continued)

Research Digest Articles

Research Digest Articles (Continued)

Contributing Editor's Collection

Editorial Advisory Board Contributions

We live in a world of heightened geopolitical risk where developed countries are reliant on less politically stable countries for the supply of many commodities. Yet there is little academic literature that investigates these relationships. This paper presents such an analysis using a new index of geopolitical risk. An initial simple event analysis is performed comparing spikes in geopolitical risk with the performance of various financial markets. The results are ambiguous: the relationships vary enormously over time and across financial indices. A vector autoregressive analysis is performed to examine the relationships more closely. Granger causality from commodity prices to geopolitical risk is shown to have existed before the global financial crisis but not subsequently. Impulse response analysis generally shows a weak response both from commodities to geopolitical risk as well as in the other direction. This is in contrast with commonly held views about the impact of geopolitical risk on commodity prices.

This article is the second in a two-part series. This series provides insights into the complex dynamics of oil price formation from 2014 onwards. Part 1 focused on the events influencing the oil markets from 2014 through 2015 while Part 2 covers (a) oil-market-moving events from 2016 through the present and near future and (b) JOSCO Energy Finance and Strategy's field-by-field oil production analysis through 2025.

In recent years, positioning has become a key driver of commodity prices and a principal factor in shaping sentiment and behavior. Published in January 2018, the book, Positioning Analysis in Commodity Markets, defines and establishes "Positioning Analysis" as an area of research that provides a powerful framework to better understand price dynamics, risk, sentiment and behavior in commodities. The article highlights key areas of the book, explaining how certain types of positioning patterns, in the context of changes in a variety of variables, can be used to develop different models, indicators, analyses and trading signals.

Industry Commentary

Market risk and hedging strategies have, particularly over the last few years, helped many market participants mitigate crude oil market fluctuations. The implementation of efficient energy hedging strategies has often made the difference between business success and bankruptcy. An indispensable element of hedging is the estimation of volatility. This article explains how a study of volatility fluctuations can be used to build efficient hedging strategies and to understand market sentiment. The key features of this analysis focus on volatility asymmetry and volatility's mean-reversion propensity. The article finds a negative link between implied volatility, extracted from average price options, and swap prices in both the Brent and WTI markets, implying an asymmetric volatility response to changes in the underlying price. The mean-reversion propensity of volatility is also found to be rather strong in both crude grades under examination.

Interview

We are delighted to interview Dr. James Hamilton, Ph.D., Professor of Economics, University of California, San Diego and Co-Chair of the JPMCC's Research Council. Professor Hamilton also serves as the JPMCC's Distinguished Visiting Fellow. In this issue's interview, Professor Hamilton explains what originally spurred his interest in the impact of oil price increases on the economy, followed by what he currently sees as important research issues. He also touches on what encouraged him to become involved with the JPMCC and its Research Council, noting some of his goals for the Research Council and its international commodity symposia. The interview concludes with Professor Hamilton discussing both the potential impact the JPMCC could have on the commodity industry and his recommendations for future topics in the *GCARD*.

Professional Society Partnership

The International Association for Quantitative Finance (IAQF) is a prestigious professional society that is partnering with the *Global Commodities Applied Research Digest*. The IAQF is dedicated to fostering the profession of quantitative finance by providing platforms for the discussion of cutting-edge and pivotal issues in the field. Founded in 1992, the IAQF is composed of individual academics and practitioners from banks, broker dealers, hedge funds, pension funds, asset management firms, technology firms, regulatory bodies, accounting, consulting and law firms, and universities across the globe.

The *Global Commodities Applied Research Digest* (*GCARD*) is produced by the J.P. Morgan Center for Commodities (JPMCC) at the University of Colorado Denver Business School. The University of Colorado Denver Business School is led by Dr. Rohan Christie-David, Ph.D., Dean and Professor of Finance. The JPMCC's Research Director is Dr. Jian Yang, Ph.D., CFA, who is also the J.P. Morgan Endowed Research Chair and Professor of Finance and Risk Management.

Dr. Rohan Christie-David, Ph.D., Dean of the University of Colorado Denver Business School and Professor of Finance, thanking participants at the conclusion of the J.P. Morgan Center for Commodities' inaugural international commodity symposium, which was held at the University of Colorado Denver Business School from August 10, 2017 through August 11, 2017.

The JPMCC's Program Manager is Mr. Matthew Fleming.

The aim of the *GCARD* is to serve the JPMCC's applied research mission by informing commodity industry practitioners on innovative research that will either directly impact their businesses or will impact public policy in the near future. The digest is published twice per year and has been made possible by a generous grant from the CME Group Foundation.

The *GCARD*'s Contributing Editor is Ms. Hilary Till, M.Sc. (Statistics), Solich Scholar at the JPMCC and member of the JPMCC's Research Council. In addition, Ms. Till is a Principal of Premia Research LLC. The *GCARD*'s Editorial Assistant is Ms. Katherine Farren, CAIA, whom, in turn, is also a Research Associate at Premia Research LLC.

The *GCARD*'s logo and cover designs were produced by Jell Creative, and its website was created by Pink Shag Design. The *GCARD*'s layout was conceived by Ms. Barbara Mack, MPA, of Pingry Hill Enterprises.

The *GCARD* is cosponsored by ESSEC Business School's Energy and Commodity Finance Research Center (ECOMFIN). Professor Andrea Roncoroni, Ph.D., is the director of ECOMFIN (France, Singapore) and serves on the *GCARD*'s Editorial Advisory Board.

Update from the Research Director of the J.P. Morgan Center for Commodities (JPMCC)

Jian Yang, Ph.D., CFA
J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Professor of Finance and Risk Management, University of Colorado Denver Business School

Professor Jian Yang, Ph.D., CFA, updated the J.P. Morgan Center for Commodities' (JPMCC's) Advisory Council members on the JPMCC's research goals and plans during the Advisory Council's meeting on March 8, 2018.

It is my great honor to serve as the first J.P. Morgan Endowed Chair and Research Director for the J.P. Morgan Center for Commodities (JPMCC), a role I have held since September 2017. In my opinion, the JPMCC is well positioned to be a leading commodities research center in the world for the following reasons.

First, the JPMCC has an excellent location in the U.S. The U.S. is the largest economy in the world, and we are the only research center focusing on commodities broadly as an asset class in the U.S.

Second, the JPMCC has unique international connections. In particular, the center has strong ties with China and some other Asian economies, and aims to be a thought leader in commodity research in Asia and beyond.

Third and most importantly, the JPMCC embraces contemporary perspectives. Different from programs specializing in agricultural, energy or mineral economics, the JPMCC has integrated perspectives in conducting research and education in commodities. In particular, we have (a) the integration of economic and financial perspectives, (b) the integration of fundamental and behavioral perspectives, and (c) a broad integration of economic/financial perspectives on the one side and politics/regulatory perspectives on the other side within our commodities research and education programs. We also adopt an international perspective with particular attention to major emerging markets.

To fulfill the vision of becoming a global leader in commodity research and education, the JPMCC is pursuing the following three goals with the advice and the support from the Advisory Council and the Research Council.

First, the JPMCC aims to be a center known for its innovative research in the commodities space. Having in-house faculty members devoted to delivering high quality commodities research is essential to the credibility and reputation of the JPMCC. In September 2017, the JPMCC Research Director participated in an invited paper presentation at the U.S. Energy Information Administration's (EIA's) Financial and Physical Oil Market Linkages' Annual Workshop. In December 2017, the Research Director made a keynote speech at the 3rd Derivatives Academic Forum, part of the 13th China International Derivatives Forum organized by the China Futures Association and all four futures exchanges in China that attracted 1,400 attendees and a dozen derivatives exchanges and about 100 companies from outside of mainland China. As a result, the JPMCC (and its Research Director) has made its "first show" in China, and was featured favorably in a dozen Chinese media articles, including an exclusive interview with *The Economic Daily*, the only newspaper sponsored by the State Council of China, and two other exclusive interviews with *Futures Daily* and *China Futures* magazine. Recently, the JPMCC also substantially expanded its already excellent Research Council, which now includes distinguished scholars from Harvard, MIT, Princeton, Yale, UC-Berkeley and other world top universities as well as industry leaders from Robert Bosch GmbH (Germany), CME Group, Encana Oil & Gas USA, J.P. Morgan and Newmont Mining. In 2018, the JPMCC is starting the Distinguished Visiting Fellow program in order to invite and host leading researchers in commodities, with the first award going to the famous energy economist (and econometrician) James Hamilton at University of California, San Diego. (We are grateful that Professor Hamilton agreed to be interviewed in this issue of the *GCARD*.) The center also plans to recognize younger active researchers in its new program of Research Associates and host their visits in the near future.

Second, the JPMCC will be a leading educator of cutting-edge knowledge in the commodities space. To provide talented practitioners for the commodity industry, we have developed formal degree-seeking programs at the graduate level with a commodities specialization and are undergoing an ongoing expansion at the undergraduate level. To this end, we provide many student scholarships sponsored by major companies in the commodities space to attract excellent students and invite distinguished lecturers from universities and the industry to speak to students.

In the spring of 2018, the JPMCC hosted two distinguished lecturers: Dr. John Baffes, Ph.D., Senior Economist at the World Bank, lectured in March while Dr. Hillard Huntington, Ph.D., Executive Director of Stanford University's Energy Modeling Forum, lectured in April.

Dr. John Baffes, Ph.D., Senior Economist at the World Bank, presented on "Commodity Markets: Developments and Outlook" at the JPMCC's Advisory Council Meeting on March 8, 2018. Dr. Baffes is a member of the *GCARD*'s Editorial Advisory Board.

We have also continuously conducted various intensive courses for professional training and have offered the commodities certificate to business professionals since 2013.

Third, the JPMCC will become a major player in knowledge exchange in the commodities space. Specifically, building on the successful inaugural international commodities symposium in 2017, we will hold the second JPMCC international commodities symposium in August 2018. For the coming symposium, we will have a special issue from the *Journal of Futures Market*, a leading journal in derivatives, which includes highly relevant commodities research. Amongst the many top commodities scholars planning to attend the conference, Dr. Jeffrey Frankel, Ph.D., will deliver a keynote speech. Dr. Frankel is the James W. Harpel Professor of Capital Formation and Growth at Harvard University's Kennedy School. In addition, Dr. Frankel served on the U.S. President's Council of Economic Advisers twice (and as the Chief Economist during 1996-1997) and is currently a Research Associate at the National Bureau of Economic Research, where he is on the NBER Business Cycle Dating Committee, which officially declares recessions. The JPMCC's August 2018 symposium is expected to receive local and international media attention, with the opportunity for many presenters' findings being shared with industry professionals internationally. The JPMCC is also exploring the possibility of co-organizing additional commodities conferences abroad to expand its global reputation, with two countries in different continents currently under consideration.

Furthermore, as mentioned above, JPMCC researchers also regularly participate and deliver speeches at various academic or industry conferences on commodities, and constantly entertain media interviews to share cutting-edge knowledge on commodities to different stakeholders and the general community. Since last September 2017 (and until April 2018), the Research Director of the JPMCC has been interviewed on various commodity futures topics, resulting in news articles in over 40 media outlets (primarily newspapers, magazines, TV broadcasts, and occasionally online news media) in several different languages (i.e., English, Chinese, Italian, and Indonesian) featuring the JPMCC and reaching out to audiences in several dozen countries (e.g., U.S., China, U.K., Germany, France, Italy, Belgium, Canada, Australia, India, Russia, Singapore, Malaysia, Greece, Indonesia, Qatar, Kenya, South Africa, Nigeria, Ethiopia, Tanzania and Ghana). These include the English-language media such as *Bloomberg*, *Forbes*, *China Daily USA*, Russian international television network RT, *China Daily-European Weekly* (based in the U.K.), A*ustralian Financial Review*, *The Business Times* (in Singapore), *China Daily-African Weekly* (based in Kenya), and major Chinese newspapers such as *Economic Daily* (of the State Council of China), *China Securities Journal* (of Xinhua News Agency), *Economic Information Daily* (of Xinhua News Agency), *Financial Times* (of People's Bank of China), among others. These articles are also further posted on numerous news websites internationally.

I am pleased with the fruitful efforts we have made thus far in advancing the vision and the mission of JPMCC, particularly in the research arena. With excellent input and strong support from various stakeholders, the JPMCC will become a leading center in commodities research and education in the world, despite challenges ahead.

Jian Yang, Ph.D.

J.P. Morgan Center for Commodities (JPMCC) Advisory Council

The JPMCC's Advisory Council consists of members of the business community who provide guidance and financial support for the activities of the JPMCC, including unique opportunities for students. With the support of the Advisory Council, the JPMCC aims to become a global leader in commodities education and applied research. The JPMCC is grateful for the Advisory Council's staunch support of its activities!

Mr. Colin Fenton, Managing Partner and Head of Research, Blacklight Research LLC, responds to a point during the JPMCC's Advisory Council Meeting held on March 8, 2018. Mr. Fenton is a member of the J.P. Morgan Center for Commodities' Research Council as well as Co-Chair of the JPMCC's Advisory Council. To Mr. Fenton's right is Mr. Christopher Calger, Managing Director, J.P. Morgan, and Co-Chair of the JPMCC's Advisory Council.

The corporate members of the JPMCC's Advisory Council are listed on the next page.

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FourPoint Energy, LLC	*Whitewave Foods Company*
Hammond International Group	*Xcel Energy*

J.P. Morgan Center for Commodities (JPMCC) Research Council

The JPMCC is honored to have a distinguished Research Council that provides advice on shaping the research agenda of the Center. Amongst its articles, the *GCARD* draws from insightful presentations and discussions by the JPMCC's Research Council members. The JPMCC's Research Council is listed on the next page.

Dr. Scott Irwin, Ph.D., Laurence J. Norton Chair of Agricultural Marketing in the Department of Agricultural and Consumer Economics at the University of Illinois at Urbana-Champaign, presenting at the JPMCC's international commodities symposium, "New Directions in Commodity Research," which was held at the University of Colorado Denver Business School on August 10 through August 11, 2017. Dr. Irwin is a member of the JPMCC's Research Council.

J.P. Morgan Center for Commodities Research Council Members

Jian YANG, Ph.D., CFA, J.P. Morgan Endowed Chair & JPMCC Research Director
University of Colorado Denver Business School

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Contributing Editor's Letter

Hilary Till
Solich Scholar, J.P. Morgan Center for Commodities (JPMCC), University of Colorado Denver Business School; and Contributing Editor, *Global Commodities Applied Research Digest (GCARD)*

Ms. Hilary Till, the Contributing Editor of the *Global Commodities Applied Research Digest (GCARD)*, provided an update on the *GCARD* to the J.P. Morgan Center for Commodities' Advisory Council during the council's meeting on March 8, 2018.

Dear Reader,

Welcome to the fifth issue of the *Global Commodities Applied Research Digest*! The current issue draws from the J.P. Morgan Center for Commodities' (JPMCC's) large body of international experts, whom are affiliated with the center either through the JPMCC's Research Council, Advisory Council, or through the *GCARD*'s Editorial Advisory Board. Consistent with the JPMCC's varied expertise, this issue includes articles that analyze the commodity markets from both fundamental and quantitative perspectives.

In addition, this issue has a special focus on the JPMCC's inaugural international commodity symposium, which was held in August 2017. In future issues of the *GCARD*, we look forward to covering the second international commodity symposium, which will take place in August 2018. The forthcoming conference is being organized by the JPMCC's Research Director, Professor Jian Yang. (Professor Yang is also the J.P. Morgan Endowed Research Chair.)

This issue of the *GCARD* is divided into the following seven sections: (1) the Research Council Corner; (2) the Reports on Research Council Meetings section; (3) the Research Digest Articles section; (4) the

Contributing Editor's Collection; (5) the Editorial Advisory Board Contributions section; (6) the Industry Commentary section; and (7) an Interview with a Thought Leader in Commodities.

In this issue's **Research Council Corner**, our authors separately examine macroeconomic risks and complex contract risks. In the former article, Dr. Bluford Putnam of the CME Group assesses the challenges of trade protectionism. In the latter article, Dr. Brock Mosovsky of cQuant.io and Lance Titus of Uniper Global Commodities evaluate the subtle risks embedded in renewable power purchase agreements. Both Dr. Putnam and Mr. Titus are members of the JPMCC's Research Council.

Mr. Lance Titus (left), Managing Director, Uniper Global Commodities, with Mr. Matthew Most, Vice President, Encana, during a panel session at the JPMCC's September 30, 2016 Research Council meeting. Mr. Titus co-authored an article for this issue of the *GCARD*. He is a member of both the JPMCC's Advisory Council and its Research Council and joined the *GCARD*'s Editorial Advisory Board this year.

The **Reports on Research Council Meetings** section covers the JPMCC's August 2017 international commodity symposium, which took the place of the JPMCC's annual Research Council meeting. Our initial coverage of the symposium began in the [Winter 2017 issue] with Ms. Jodie Gunzberg of S&P Dow Jones Indices, summarizing her presentation on "[Chinese Economic Growth and Commodity Performance]." The current issue of the *GCARD* includes summaries from two additional presenters: Professor Lutz Kilian of the University of Michigan, Ann Arbor, co-authored a digest article, which is based on his keynote presentation on oil prices and the economy, and Dr. Martin Stuermer of the Federal Reserve Bank of Dallas authored a digest article, which is based on his symposium lecture on commodity price booms and busts. Two additional conference participants, Dr. Kaifeng (Kevin) Chen of Hywin Capital Management, LLC and Dr. Keith Black of the Chartered Alternative Investment Analyst Association, along with Ms. Lena Gerber of the University of Colorado Denver, summarize the following four additional topics that were covered during the conference: (1) the business of rare earth metals; (2) renewable energy public policy; (3) the potential impact of distributed ledger technology on markets; and (4) the connection of China's credit cycle to industrial metals demand. Both Dr. Chen and Dr. Black are members of the *GCARD*'s Editorial Advisory Board.

Dr. Kaifeng (Kevin) Chen (left), Ph.D., Chief Strategist, Hywin Capital Management, LLC, in discussion with Dr. Martin Stuermer, Ph.D., Research Economist, Federal Reserve Bank of Dallas after Dr. Chen's presentation at the JPMCC's August 2017 international commodities symposium. Both Dr. Chen and Dr. Stuermer contributed articles to this edition of the *GCARD*.

In the **Research Digest Articles** section, Professor Ana-Maria Fuertes of Cass Business School, City, University of London (U.K.) generously summarizes three scholarly papers, each of which discuss a different application of quantitative methods to commodity futures trading. Professor Fuertes is also a *GCARD* Editorial Advisory Board member.

The **Contributing Editor's Collection** of digest articles covers two sets of case studies. While the Winter 2017 issue of the *GCARD* covered the bankruptcy of the Futures Commission Merchant / Broker Dealer, MF Global, this issue of the *GCARD* reports on the Amaranth (commodity) hedge fund debacle. The section's second case study recounts the historical circumstances that led to the establishment of futures contracts. The latter article is excerpted from a lecture that was provided by the author to staff from the Shanghai Futures Exchange.

In the **Editorial Advisory Board (EAB) Contributions** section, three EAB experts provide articles on the following topics: (1) the impact of geopolitical risk on commodity prices; (2) the history of past oil price surprises along with predictions through 2025; and (3) the analysis of commodity positioning data. The authors for these timely articles are respectively Dr. Daniel Murray of EFG Asset Management (U.K); Mr. Jan-Hein Jesse of JOSCO Energy Finance and Strategy Consultancy (Amsterdam); and Mr. Mark Keenan of Société Générale Corporate & Investment Bank (Singapore).

The **Industry Commentary** section includes an article on how a study of the statistical properties of oil price volatility can assist in the design of efficient hedging strategies. This article is by Mr. Vito Turitto of S&P Global Platts (U.K.).

In this issue’s **Interview with a Thought Leader in Commodities**, we interview Professor James Hamilton of the University of California, San Diego. Professor Hamilton is also the Co-Chair of the JPMCC’s Research Council and is a Distinguished Visiting Fellow at the JPMCC. Professor Hamilton's advanced econometrics textbook, Time Series Analysis, is widely used by researchers in modeling the economy. In addition, his research has helped to guide U.S. monetary policy. Importantly for the JPMCC, Professor Hamilton is widely published on the impact of oil price increases on the economy. We are grateful for Professor Hamilton’s affiliation with the JPMCC.

In conclusion, we would like to thank the CME Group Foundation for sponsoring the *GCARD*, and we welcome the International Association for Quantitative Finance as the *GCARD*’s inaugural professional society partner.

Best Regards,

Hilary Till

Hilary.Till@ucdenver.edu

Contributing Editor, *Global Commodities Applied Research Digest*; and
Solich Scholar, J.P. Morgan Center for Commodities, University of Colorado Denver Business School

Let the Trade Skirmishes Begin

Bluford Putnam, Ph.D.
Chief Economist, CME Group; and Member of the J.P. Morgan Center for Commodities' (JPMCC's) Research Council at the University of Colorado Denver Business School

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The trade skirmishes began in earnest in March 2018 with the U.S. imposing tariffs on steel and aluminum in the name of national security. The U.S. temporarily exempted Mexico and Canada pending progress on the NAFTA negotiation and held open the possibility that other countries might be exempted. Had the European Union (E.U.) not gained a temporary exemption, the E.U. would have retaliated with highly focused tariffs, from jeans to bourbon to motorcycles, designed to hit some hot-button pain points involving name-brand companies.

Also, in March, a group of 11 nations, without the U.S., signed the Trans-Pacific Partnership, renaming it the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), which cuts tariffs among the partnering nations. The signing of the CPTPP underscores the U.S. withdrawal from a leadership role in multilateral global affairs and reaffirms the intent of many other countries to strengthen mutual trade ties. This has the potential to reshape long-term trading patterns in goods, services, and commodities in a way that would disadvantage U.S.-based companies and producers.

Also in progress in the spring of 2018 are the U.S.-Canada-Mexico negotiations over the North American Free Trade Pact (NAFTA). While technical committees involved in the negotiations reportedly have made some progress on the small issues, the big issues that separate the U.S. from Canada and Mexico revolve around domestic-content rules (think autos) and how to handle disputes (the U.S. wants a system more to its liking) are far away from being solved. Indeed, while the U.S. rhetoric about unfair trade practices is often aimed at China, the steel and aluminum tariffs can also be seen as bargaining chips in the NAFTA negotiations. Our takeaway is that the U.S. is only a very short step away from announcing its intention to withdraw from NAFTA. We note that announcing the intention to withdraw triggers a 6-month waiting period. At the end of the 6-months is when the final decision to withdraw or not would be made.

Finally, the "Brexit" negotiations between the United Kingdom (U.K.) and European Union (E.U.) for the U.K. to exit the free trade zone are not going well – actually they are not moving much at all. The U.K. has tended to negotiate as if they were equals with the E.U. By analogy, though, if this were a card game, the E.U. holds four aces and the U.K. does not have a single pair – yet the U.K. continues to bluff for better terms, even though everyone's cards are on the table for all to view. The strategy is not working because there are some fundamental inconsistencies at its heart. The first problem for U.K. Prime Minister May is that the Conservative Party is split with some hard Brexit advocates and some soft Brexit advocates. Another problem for the U.K. is Ireland. U.K. Prime Minister May has promised to treat Northern Ireland the same as England, Scotland and Wales. Prime Minister May has also promised the Democratic Unionist Party (DUP), whose ten votes she needs to remain in power in Parliament in Westminster, that she will keep an open border between the Republic of Ireland and Northern Ireland. It is very hard to conceive of how one keeps an open border with Ireland, without putting some border controls in place between Northern Ireland and the rest of the U.K. And, how do you keep free trade between Northern Ireland and the Republic and yet impose different rules on the rest of the U.K. versus the E.U.? It just does not add up.

Thus, the odds have risen that either the Conservative Party will revolt and select a new Prime Minister, or the DUPs will withdraw their 10 votes and force a new election. If there is a new election, the Labour Party would have a reasonable chance to win; indeed, they might even be favored. What this means for trade between the U.K. and E.U. is that the U.K. is currently headed down a path in which it will miss the 2019 deadline for a deal to leave the E.U., and the E.U. may just say goodbye and force a hard Brexit, meaning more political repercussions in the U.K. and damage to U.K. trade with the E.U.

In short, the sources of trade tensions are getting increasingly serious. The U.S. is moving unilaterally to impose tariffs, the CPTPP-11 are moving to create a customs zone without the U.S., the renegotiation of NAFTA is about to hit major roadblocks, and no Brexit deal is in sight, increasing the odds of a "hard" exit for the U.K. and the worst case for U.K.-E.U. trade.

What are the Economic Implications of Rising Trade Tensions?

There are considerable complex interactions in play when considering the implications of the path global trade negotiations have taken. While some politicians prefer to look at trade through a bilateral lens that focuses on the net trade in goods between two countries, modern trade patterns are incredibly interconnected, involving trade in goods, services, and commodities, with direct and indirect implications on how trade flows are financed and how capital flows among countries. Our analysis here focuses on a select few of the challenges that highlight the complex network of trade and capital flows that could be potentially disrupted if growing trade tensions expand into a shift toward nationalist, protectionist policies.

<u>Global Growth</u>

2017 global growth was a solid improvement over 2016, and 2018 seems on track to exceed 4% real GDP growth. This accelerated pace of activity represents a synchronized growth path among virtually all regions and countries – a rising tide that is lifting all boats. The laggards of 2015-2016 were Brazil due to its political problems and Russia due to the oil price declines. Both of these countries are growing again. The mature industrial countries, from the U.S. to Europe to Japan, are incrementally growing just a little bit faster.

China represents one of the major risks to world growth, but the Government has successfully managed to cushion the impact of an aging population and focused on a transition to a domestic growth model. Debt loads are very worrisome for China. Since China's debt is domestic, not owed to foreigners, and not denominated in other currencies, such as the U.S. dollar or the Euro, China probably has the tools to manage this challenge. All in all, a modest deceleration of growth in China in 2018-2019 is not expected to disrupt the higher pace of global growth overall.

The big risks to global growth are the rising trade tensions. So far, the initial salvos and skirmishes amount to very small potatoes. If a tit-for-tat tariff war starts to bite, the rosy growth scenario might dim. Economists all remember the U.S. imposing the highly restrictive Smoot-Hawley Tariffs in 1930, and along with Federal Reserve inaction, trade protectionism helped to turn a recession into the Great Depression.

Retaliation

One of the big questions as the U.S. embarks on a path of unilateral imposition of selected tariffs is what kind of retaliation might occur. We enter the world of game theory, and it is not pretty. The prevailing view among the developed world nations from Asia to Europe to Canada and Mexico is that the imposition of new unilateral tariffs has to be checked. Two responses are almost certain: (a) selectively impose retaliatory tariffs and (b) simultaneously bring legal proceedings to the World Trade Organization. For the most part, if all that happens is one side fires a shot, and the other side returns fire, which is followed by a cease fire, then the damage to global economic growth is likely to be quite small. The real danger is that trade pacts that have been in place start to unravel. That would be the case if the U.S. pulled out of NAFTA or there was a hard exit for the U.K. from the Europe customs union. This heightens the importance for markets if NAFTA or Brexit go badly, and one can expect stock markets to get quite jittery if the rhetoric gets cranked up.

The question of retaliation often revolves around who feels the pain. For example, the U.S. Administration is taking a calculated bet that the gains to the steel and aluminum industries will be meaningful and measureable, while the pain felt by industries that use steel and aluminum, from beer and soft drink companies, to aircraft companies, to oil and gas well drillers will be spread wide enough not to be easily attributable to the new tariffs. The argument goes that if the impact is less than a penny a beer can, no one will notice. The reality is that the companies hit by the "friendly-fire" will see it in their bottom lines and stock prices, and they will be less able to make new investments or create jobs. So, there is a political-economic disconnect, where the offsetting economic losses are not felt politically but are felt in the stock market, labor markets, and the economy.

The strongest case for protectionism has always revolved around emerging market countries. The idea was that tariffs could protect domestic industries from international competition, giving them time to develop and flourish. A developing nation might award a monopoly to give a local telephone company a protected environment to build cell phone service. Or, a national oil company would be protected from foreign competition so as to build up the domestic capabilities. Unfortunately, protectionism of this sort also seems to breed crony capitalism and industrial-political corruption. For a case study, one can examine Brazil's "Car Wash" initiative to clean up the corruption partly caused by protectionist policies.

Most economists, although not all, have railed against protections. Mercantilist polices held sway in the 1500 and 1600s, as the national objective was focused on accumulating gold and having a strong navy. The French economics minister for the Sun King Louis XIV was Jean-Batiste Colbert, and he was a key figure in promoting trade protectionism. By the 1700s, the free trade ideas of philosopher and political economist David Hume were gaining ground. In the early 1800s, David Ricardo's theory of comparative advantage helped to build the foundation of why and how free trade led to much greater economic growth. Hume made the case eloquently as he argued:

> " … there still prevails, even in nations well acquainted with commerce, a strong jealousy with regard to the balance of trade, … This seems to me, almost in every case, a groundless apprehension; and I should as soon dread, that all our springs and rivers should be exhausted, as that money should abandon a kingdom where there are people and industry. Let us carefully preserve these latter advantages; and we need never be apprehensive of losing the former." (From David Hume, *Essays, Moral, Political, and Literary*, 1752, Part II, Section V).

Diversification of Sources of Imports

Just the risk of the demise of NAFTA or a hard Brexit has already caused trade patterns to shift a little. Mexico has started importing corn from Brazil. Mexico will also be taking a hard look at how its energy resources are managed so as to lessen its growing dependency on U.S. natural gas. The U.S. is also a big exporter of cattle and beef products to Mexico that could soon face new competition from other countries. Mexico could also target cattle and beef imports for retaliatory tariffs.

Companies have responded as well. Some financial companies have stopped hiring in London and are starting to make plans for expanded operations inside the E.U. Japanese companies have long understood the risks of relying on production facilities in China and many years ago adopted the "China plus one" approach to making sure they had supply chain capabilities outside of China.

U.S. multinationals will often find themselves between a rock and a hard place. To take advantage of the new CPTPP, production and service support facilities may need to be physically located inside one of the 11 countries in the Trans-Pacific Partnership or else the companies risk losing access to the those markets on competitive terms.

Rise of China as Global Power

One of the key global consequences of the U.S. withdrawal from a leadership role for free trade and other multilateral initiatives is the opening this policy shift has given to China to expand its influence much more rapidly than many had thought possible and to increasingly play the leading role in global affairs that it has long coveted. China is typically every nation's number one or number two trading partner. All of the small nations in the Pacific region have significant China risk regarding their own economies. Moreover, China is extremely aggressive in trying to influence the production of commodities that are essential to its economy. China's President Xi Jinping has recently moved to consolidate his power and to govern for life. While China's rise as an economic power eventually would have given it a central place on the world's stage, China's more dramatic ascendency is a game-changer for countries in the Pacific region and how they manage their own trade relationships with China.

Capital Flows

All trade flows are financed by capital flows. This accounting observation should also be viewed from the opposite perspective. Namely, countries that provide attractive investment opportunities and are net attractors of capital will naturally run deficits in the balance of trade for goods and services. The point here is that trade flows do not necessarily drive capital flows and vice versa. The arithmetic that a negative (positive) balance on goods and services will be offset by positive (negative) net capital flows implies no direction of causality.

The corollary point is that a rise in trade protectionism will impact capital flows as much or even more than trade flows as markets adjudicate prices and allocate resources in the changed environment. Indeed, we would argue that a rise in trade protectionism is likely to have quite profound impacts on capital flows, particularly for the United States because of the role of the U.S. dollar as the primary reserve currency and the primary currency of denomination for commodity pricing.

Let's take trade with China as an example. The U.S. imports large quantities of consumer goods from China. China imports large quantities of U.S. Treasury securities from the U.S. U.S. consumers acquire consumer goods at cheaper prices than they could be manufactured domestically, and China acquires the national debt of the United States. And, all of this trade, real goods for paper assets, occurred willingly and as Milton Friedman (*Capitalism and Freedom*, 1962) often said: "The most important single central fact about a free market is that no exchange takes place unless both parties benefit." If the U.S. shift toward trade protectionism causes U.S. Treasury securities to be less desirable, as might arguably be the case as U.S. economic and trade policy risk rises, then the U.S. would see a rise in yields on U.S. Treasury securities and a rise in the interest expense incurred by the federal government on new issues of Treasury securities.

The increased riskiness of the U.S. dollar may well explain a conundrum for some economists in 2017. During 2017, the U.S. Federal Reserve (Fed) was raising short-term interest rates, announcing plans to shrink its balance sheet and reverse quantitative easing, while the European Central Bank (ECB) and the Bank of Japan (BoJ) continued to expand their balance sheets and keep short-term rates near zero. The U.S. dollar weakened against both the euro and the Japanese yen. If one believes exchange rates are partially driven by relative monetary policy, then this was the opposite of what was expected. If one also believes that a change in relative risk requires a higher risk premium, then one can start to appreciate the impact of policy uncertainty on the U.S. dollar and U.S. Treasury yields.

How to Create a Trade Surplus: Have a Recession

The easiest way, although not recommended, for a major country to create a trade surplus is to have a recession. Import demand is driven by economic growth. Remove the economic growth, and import demand will collapse. While it is probably not true, if other things remained equal, then the country in recession would still export goods while its imports would collapse. If a country's economic performance outpaces the rest of the world, its demand for imports will rise relative to exports to the rest of the world. We are just trying to underscore the observation of David Hume that one should not make value judgments about trade deficits or surpluses. If a nation takes care of its economic growth, money flows; trade and capital will take care of themselves.

Endnotes

All examples in this report are hypothetical interpretations of situations and are used for explanation purposes only. The views in this report reflect solely those of the author and not necessarily those of CME Group or its affiliated institutions. This report and the information herein should not be considered investment advice or the results of actual market experience.

Author Biography

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Dr. Bluford Putnam is Managing Director and Chief Economist of CME Group. He manages the Intelligence & Analytics team, which includes both data science and management analytics. As Chief Economist, Dr. Putnam is responsible for leading the economic analysis on global financial markets by identifying emerging trends, evaluating economic factors and forecasting their impact on CME Group and the company's business strategy. He also serves as CME Group's spokesperson on global economic conditions and manages external research initiatives.

Prior to joining CME Group, Dr. Putnam gained experience in the financial services industry with concentrations in central banking, investment research and portfolio management. He most recently served as Managing Partner for Bayesian Edge Technology & Solutions, Ltd., a financial risk management and portfolio advisory service he founded in 2000. He also has served as President of CDC Investment Management Corporation and was Managing Director and Chief Investment Officer for Equities and Asset Allocation at the Bankers Trust Company in New York. His background also includes economist positions with Kleinwort Benson, Ltd., Morgan Stanley & Company, Chase Manhattan Bank and the Federal Reserve Bank of New York. Dr. Putnam holds a bachelor's degree in liberal arts from Florida Presbyterian College (later renamed Eckerd College) and a Ph.D. in economics from Tulane University.

Dr. Putnam has authored five books on international finance, as well as many articles that have been published in academic journals, including the *American Economic Review*, *Journal of Finance*, and *Review of Financial Economics* among others.

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Lifting the Veil on Hidden Risk in Renewable Power Purchase Agreements

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Mr. Lance Titus (left), Managing Director, Uniper Global Commodities, and co-author of this article, in discussion with Dr. Vince Kaminski (right), Ph.D., Professor in the Practice of Energy Management, Rice University, at the September 30, 2016 JPMCC Research Council meeting at the University of Colorado Denver Business School. Mr. Titus and Dr. Kaminski are both members of the JPMCC's Research Council.

Renewable power purchase agreements (PPAs) have long been important enablers of renewable energy development. They are a means to both providing the revenue certainty that project developers need to secure financing for capital-intensive wind and solar projects, and giving renewable energy buyers access to the renewable energy they desire without upfront capital outlay or the need for development expertise. As with any structured transaction, these benefits come with a specific set of risks. Renewable PPAs can span fifteen years or more and their long-term value depends on the future states of the notoriously volatile physical and financial electricity markets. The intermittency and volatility of solar or wind energy produced under a renewable PPA means that, once the contract is signed, the buyer is locked into a financial arrangement over which he/she has very little control. As such, there is significant risk to the PPA buyer that adverse market moves may devolve a once attractive and prudent PPA into a liability that generates significant negative cash flow on a monthly basis.

This article, the first in a two-part series on the risks associated with renewable PPAs, focuses on how rigorous analysis to support purchase decisions can help buyers properly understand and assess PPA value and risk on a project-by-project basis. We provide a statistical description of location-specific renewable resource density and intermittency, and we demonstrate how alignment between generation intermittency and variability in locational marginal electricity prices ultimately drives PPA value. To do this, we present results from a case study based on the Pennsylvania Solar Park in Nesquehoning, PA, illustrating uncertainty in monthly settlement cash flows and the total value of energy generated under a hypothetical hub-settled virtual PPA. We also discuss how future increases in renewable penetration on the grid may potentially result in additional downside risk for PPA purchasers.

The second article in the series, to be published in the Winter 2018 edition of the *Global Commodities Applied Research Digest* (*GCARD*), will outline specific strategies for actively monitoring and mitigating downside risk for buyers entering into renewable PPAs. It will build on the case study presented in the present article and will demonstrate the risk-reduction benefits of a targeted hedging strategy, discussing how active monitoring and management of PPAs can mitigate the risk of value loss over the contract lifetime.

Background

Prior to 2010, electric utilities were the most common buyers or “offtakers” of renewable PPAs. Most agreements were physical deals, meaning the utility actually took title to the physical electricity produced at the metered receipt point, passing it on to its customers through existing transmission and distribution infrastructure. With demand for renewable energy rising among large corporations with aggressive sustainability targets, a new financial product called a synthetic or “virtual” PPA (VPPA) was eventually developed as a more flexible alternative to traditional physical PPAs.

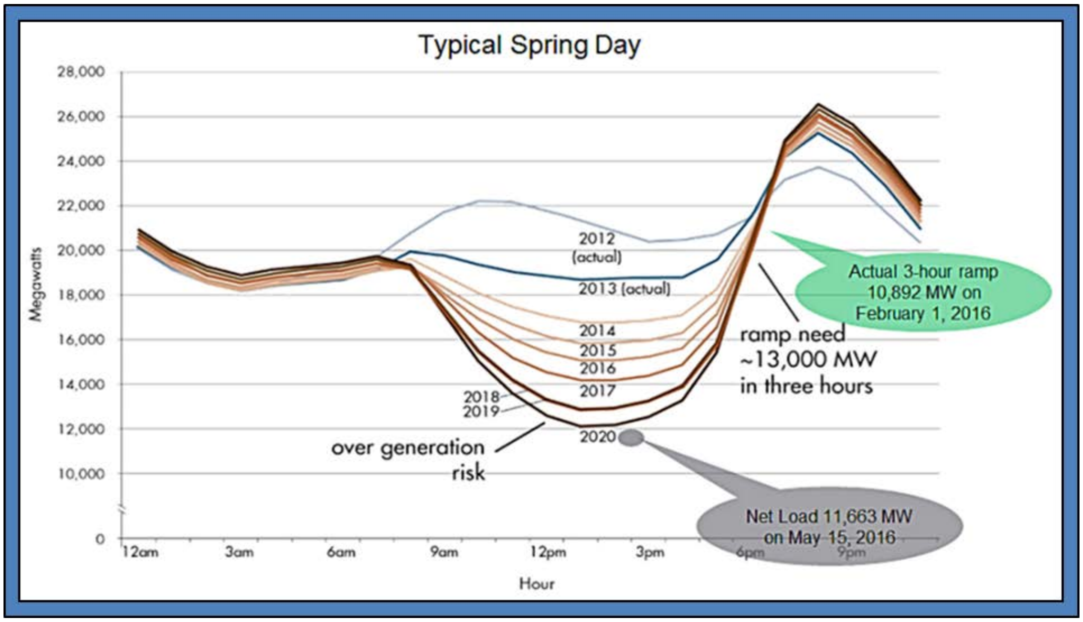
The VPPA, or “contract for differences” (CFD), provides a way for a company to acquire the renewable attributes (renewable energy credits, or RECs, and “additionality”) of new wind and solar projects without having to take actual title to the physical electricity produced. This enables a company whose primary focus is not the generation and distribution of electricity to offset its carbon footprint and progress toward its renewable energy goals, while also laying reasonable claim to renewable “additionality” for its efforts. Additionality is the notion that a new renewable generation facility has been built specifically to satisfy the renewable energy demands of a particular buyer. That is, without the long-term financial commitment of the buyer to purchase the renewable generation from the facility, usually under a PPA, the facility itself would never have been placed in service. Today, additionality is an essential component of many corporate sustainability programs because it establishes a credible link between the purchaser of a PPA and the actual facility producing renewable electricity under the agreement.

VPPAs are financially settled contracts under which the buyer and seller agree to a fair price for the electricity produced by a particular wind or solar facility over a particular time horizon.[1] The electricity generated by the facility is liquidated into the wholesale power market and earns the prevailing real-time wholesale power price at the settlement location at the time of generation. The buyer and seller then exchange funds each month in the amount of the difference between the contracted PPA price and the market value of electricity sold at the settlement location, hence the term "contract for differences". When the monthly production-weighted average market price of electricity is greater than the PPA price, the buyer of the PPA receives a payment in the amount of the difference; when it is lower, the buyer must make a cash payment to the seller for the difference.

While the primary motivation for entering into VPPAs may be acquiring the renewable attributes from the associated generation, the monthly cash settlement of the CFD structure means the long-term value of the energy itself can significantly impact a buyer's future balance sheet. This value is determined in the often-volatile real-time energy markets where the price of electricity may spike up to $9,000/MWh[2] or may take on negative values that force generators to pay for putting electricity onto the grid.[3] Moreover, renewable electricity generation is inherently intermittent, meaning the PPA buyer has no control over when it is produced, particularly if the deal is contracted as unit-contingent.[4] It is not an exaggeration to state that, at the most fundamental level, a VPPA is a long-term fixed-for-floating swap in one of the most volatile financial markets in the world on real-time or day-ahead settlement of a stream of energy the buyer cannot control.

If future electricity prices rise, a VPPA may generate additional revenue for the purchaser; however, if prices fall, the deal can result in significant unexpected monthly payments. With new challenges in renewable integration such as the "Duck Curve" in California due to high levels of mid-day solar generation (see Figure 1) and the significant and consistent negative wholesale market pricing in western Texas, any PPA valuation based on simply inflating today's electricity prices into the future is lacking in analytical rigor. A decision to purchase a VPPA should be based on project-specific analysis that identifies the most prominent risks associated with both generation and price uncertainty. In turn, this analysis should be used to inform and enact a well-reasoned procurement or hedging strategy that will protect the buyer from potential downside pricing events, even if at the expense of potential future upside. Without adequate downside protection, a well-intentioned VPPA aimed at renewable energy attribute procurement may contain a hidden long-term speculative component.

Figure 1
The "Duck Curve" Showing Projected Load Net of Solar within the Footprint of the California Independent System Operator (CAISO)[5]



Note: This figure was first popularized in a report by the CAISO in 2013 and has become an iconic representation of how solar generation can significantly reduce mid-day thermal load and exacerbate evening ramping requirements. The reduction in mid-day thermal load can lead to lower (or occasionally negative) marginal prices for real-time electricity.

Solar VPPA Case Study

As an example of a rigorous analysis to support a VPPA purchase decision, we present a case study for the Pennsylvania Solar Park (PSP) in Nesquehoning, Pennsylvania. With a nameplate capacity of 10 MW AC, the PSP was the largest solar facility in Pennsylvania when it began commercial operation in late 2012. The location and nameplate capacity of the facility were obtained from publicly-available data,[6] and we analyzed a hypothetical virtual PPA for electricity produced by the facility.

Our analysis assumes that the contract for differences is hub-settled on a monthly basis at the PJM Western Hub, one of the most liquidly-traded electricity pricing hubs in the world. Table 1 provides additional details on the solar project and PPA terms assumed for the analysis. We note that, while our example focuses on a solar VPPA, the same analytical framework is equally applicable to VPPAs for wind and other intermittent generation technologies as well.

Table 1
Pennsylvania Solar Park Project Details and Hypothetical VPPA Assumptions

Facility Location	Nesquehoning, Pennsylvania
Latitude, Longitude	40.8645° N, 75.8110° W
Nameplate Capacity (MW AC)	10
Buyer's Pro-Rata Capacity	100%
Buyer	iBuySolar, Inc.
Seller	Solar R Us, LLC
Fixed Price ($/MWh)	$35
Floating Price ($/MWh)	The Locational Marginal Price at the Settlement Point in the Real-Time Energy Market as determined by the Independent System Operator
Settlement Point	PJM Western Hub
Independent System Operator	PJM
Settlement Term	5 Years beginning at HE 0100 EPT on the Commencement Date
Commercial Operation Date	October 15, 2012
PPA Commencement Date	January 1, 2018
PPA Contract End Date	December 31, 2022
Performance Guarantee	None

Analyzing the Project-Specific Renewable Resource

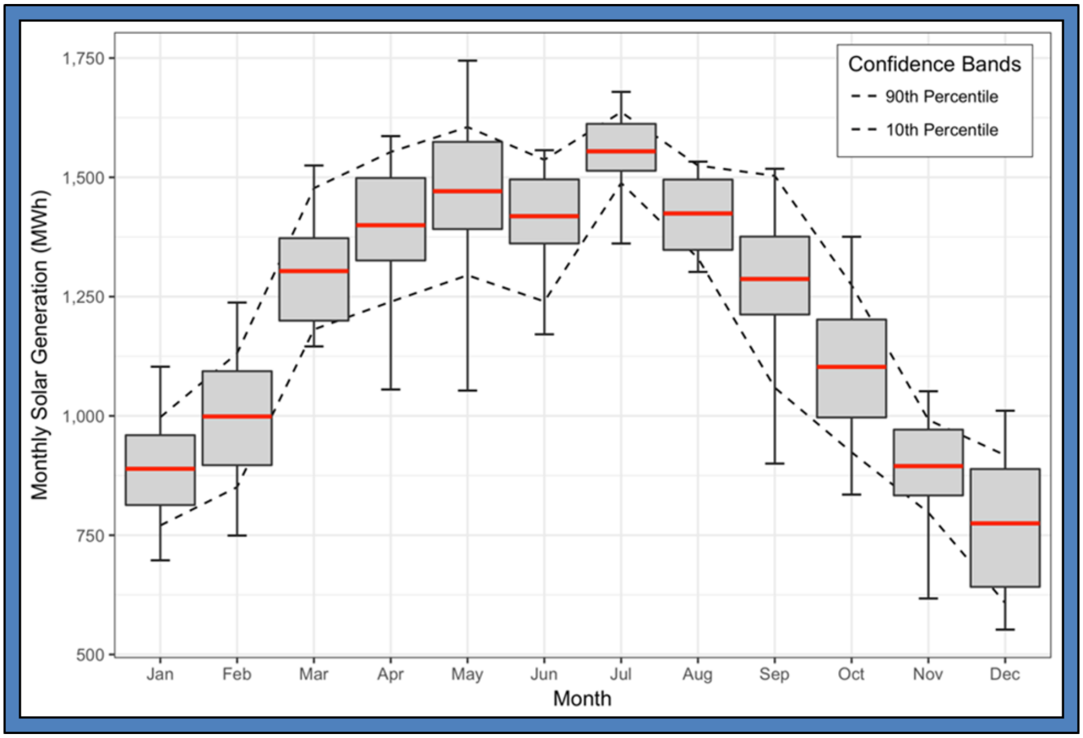
We begin analysis of the proposed VPPA by quantifying the density and intermittency of the renewable resource at the site of the generation facility. The PSP, located in northeastern Pennsylvania, will have a significantly different generation profile than a similarly-sized solar farm in, for example, Arizona. It is important to understand how generation at the particular geographic location of the PSP will vary over the course of each year, since the total value of electricity produced under the PPA is driven by the real-time facility production. In particular, it is useful to understand the expected hourly generation shape, the uncertainty around expected generation, and how each varies seasonally throughout the year. Seasonal weather attributes such as temperature, cloud cover, rain, average wind speed, and the number of daylight hours in each day all vary widely by location. Each of these significantly affects renewable resource density, the timing of renewable energy production, and the degree of uncertainty around that production.

To analyze the solar resource density and timing for the PSP, we first collected historical hourly solar radiation data at the specific latitude and longitude of the facility. We then used this data as input into the NREL System Advisor Model to compute hourly historical facility generation, and we computed various statistics from the resulting hourly production dataset. Using a model to calculate historical facility production from historical solar radiation allowed us to estimate the energy the facility would have generated even before it began commercial operation; this yielded a larger dataset for analysis than using actual metered historical production. Such a model-based approach also allows analysis of PPAs associated with renewable generation facilities that have not yet come online.

Figure 2, Figure 3, and Figure 4 below provide summary statistics from the historical analysis of renewable resource density and timing for the PSP. Figure 2 demonstrates a strong seasonality in monthly facility generation, with expected total monthly generation declining by roughly 50% between July and December.

Figure 2

Box-and-Whisker Plot Showing Variability in Historical Total Monthly Generation for the Pennsylvania Solar Park



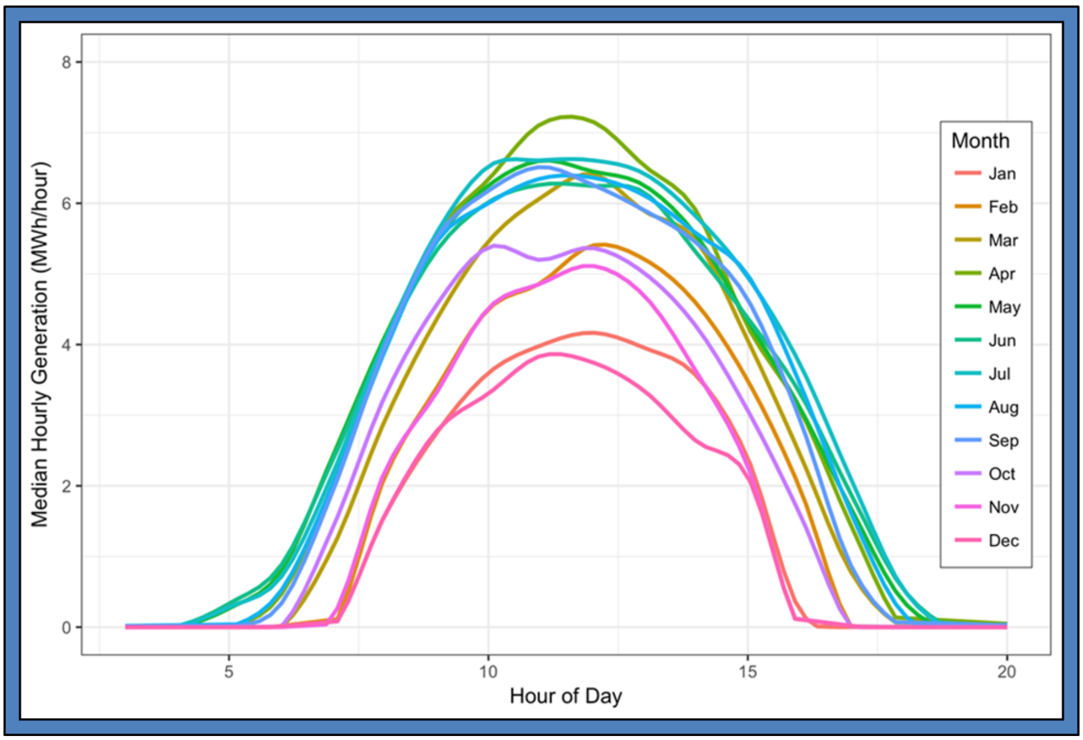
Note: The red horizontal lines indicate the expected value (average), upper and lower box boundaries indicate the P25 and P75 quantiles, and the whiskers extend to the minimum and maximum values of total generation for each month. All statistics are computed over the historical period from 1998 through 2015.

The box-and-whisker plot also nicely demonstrates the significant seasonality in monthly generation uncertainty; May and September show the greatest uncertainty as measured by the distance between the lower and upper whiskers. Significantly, while the highest expected monthly production occurs in July, the maximum production over any single historical year occurred in May at about 1750 MWh. This potential for extremely high generation in May has important implications for downside swing risk (variation in actual production of energy), which can cause significant negative monthly settlement cash flows and reduce overall PPA value. We discuss swing risk in greater detail below.

Figure 3 illustrates the seasonal variation in the diurnal generation profiles for the PSP. The curves are color-coded by month of year, and each curve represents the median generation for each hour of the day in a particular month, as computed across all historical generation data. A general seasonal trend is apparent, where months from March through September exhibit relatively commensurate generation levels while mid-day median generation falls significantly from October through February. Notably, while the total monthly expected generation is significantly higher in July than in March and September, as seen in Figure 2, mid-day median generation is much more commensurate across all of these months. This likely reflects the fact that generation during the mid-day solar peak is near system nameplate capacity from March through September, while summer total monthly generation also benefits from days with more daylight hours. Seasonal variation in the number of daylight hours is reflected in the diurnal profiles by the width of the curves for each month; as expected, median generation is positive for significantly fewer hours in the winter than in the summer.

Figure 3

Pennsylvania Solar Park Diurnal Production Curve at the Median (P50) for Each Month of the Year

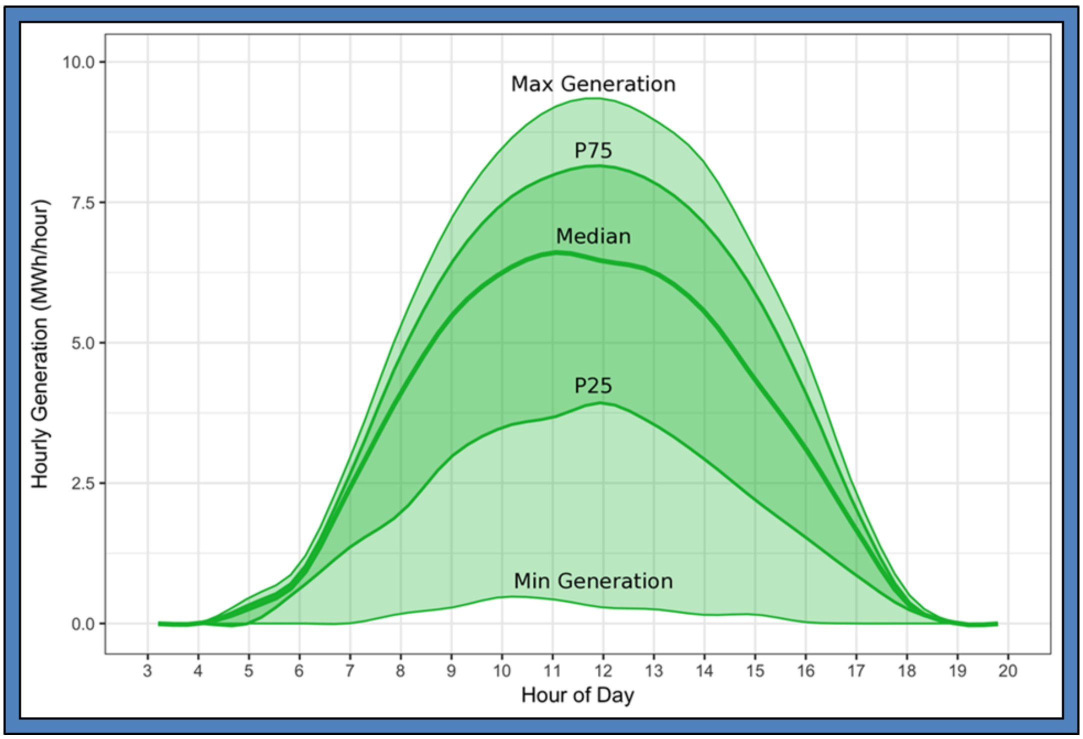


Note: The curves were constructed from 18 years of simulated historical solar generation based on hourly solar irradiance data over the same time period.

Focusing our analysis on shorter timescales reveals more variability in solar generation levels. As we disaggregate the monthly and daily generation profiles and move to the hourly level, we begin to see the true intermittent nature of the renewable resource. Figure 4 shows hourly generation statistics for the month of May, the month seen in Figure 2 to have the greatest variability in total monthly generation. Most striking in the figure is the extreme variability in production between the minimum and maximum hourly generation. Notably the upper envelope (maximum generation) for each hour is quite smooth. This is because the maximum generation is always limited by the available solar radiation in each hour; even on the clearest of days, there is an upper limit to the radiation in any given hour, and it obeys a strong and very regular diurnal pattern driven by the rotation of the earth. By contrast, the lower envelope (minimum generation) for each hour is more irregular. It is driven largely by weather patterns that obscure solar radiation and prevent it from reaching the panels. Such weather patterns are highly variable, and they impart their irregularity on the lower quantiles of hourly generation.

Finally, Figure 4 also shows that the distance between quantiles compresses as we move from minimum generation to maximum generation. This indicates that each hourly distribution of potential generation levels in May has a significant left skew. Put another way, the left tail in the distributions of hourly generation is generally longer/fatter than the right tail, which will tend to pull the expected hourly generation downward from the median. Again, this left skew is likely driven by highly variable weather events, which in any given day may decrease generation only slightly from the median or, in extreme cases, may cause the facility to generate almost nothing at all.

Figure 4
May Variability in Solar Generation by Hour



Note: Statistics were computed from 18 years of simulated historical solar generation based on hourly solar irradiance data over the same time period.

Simulating Renewable Generation and Market Prices

In addition to an understanding of seasonal and hourly patterns in generation and intermittency, an analysis of real-time market prices forms the other half of a comprehensive PPA value assessment. Electricity prices display strong quasi-periodic seasonal, weekly, and hourly patterns in both absolute price and in uncertainty around expected price. These patterns combine with the generation time series patterns discussed above to determine the value of the energy produced under the PPA. Since the value of energy produced by the facility is the product of generation and market price, the precise statistical manner in which uncertainty in prices and generation aligns determines the ultimate risk to the buyer.

The preferred way to investigate this statistical alignment is through Monte Carlo simulation of both hourly generation and hourly electricity prices over the PPA contract horizon. Our analysis used a historical simulation approach to create multiple hourly generation paths into the future by daily sampling of the historical data, with replacement. This approach yielded a time series of simulated hourly future generation that reflected the same statistical properties of the historical dataset, in aggregate, including seasonal and hourly fluctuations in generation and uncertainty. Each individual simulated hourly generation path also represented a plausible future outcome for the facility production.

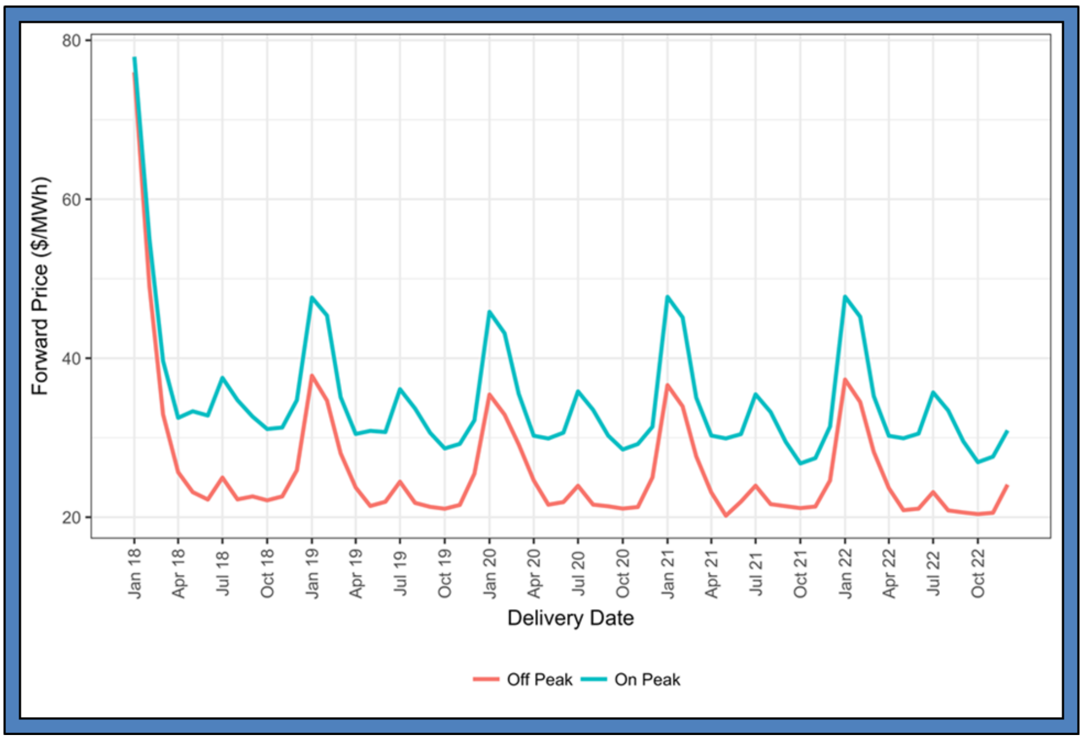
Whereas expected future renewable generation for a given month and hour of day can be reasonably well estimated through an analysis of historical data,[9] the expected future price of electricity is constantly changing in response to complex physical grid developments and financial market dynamics. One way to gain insight into the ever-changing market expectation of the future price of electricity is by examining the prices of liquidly-traded forward or futures contracts. In the case of PJM Western Hub, the settlement hub assumed for the VPPA in the present case study, exchange-traded futures contracts exist for monthly future delivery of on- and off-peak power.[10] The currently-traded futures price is a good indication of what the market believes will be the average spot price of electricity over a particular contract's delivery period. Available option-implied price volatility indications can serve as a useful guide as well.

To generate hourly simulations of future electricity spot prices, we used an autoregressive mean-reverting time series model with a jump-diffusion component. We calibrated the model against five years of historical hourly PJM Western Hub spot price history, ensuring simulated prices reflected historically-observed trends in hourly price shape, price volatility, mean reversion rate, and jump frequency and magnitude. Furthermore, we allowed each of these model parameters to vary by calendar month. The resulting price simulations provided a historically-consistent representation of the most important location-specific electricity price attributes for determining the energy component of the PPA value and inherent risk. To align these price simulations with current market sentiment, we ensured that the average simulated price in any future month was equal to the current futures contract price for that month. Enforcement of this "no arbitrage" modeling condition resulted in price simulations that were risk neutral with respect to current market expectations of the future price of electricity.

Figure 5 shows the on- and off-peak futures contract prices for PJM Western Hub power that were used in the model calibration process. Contract prices shown in the figure were as of January 12, 2018 for delivery ranging from balance-of-month through December of 2022. As can be seen in the figure, there is a very strong seasonal component to both the on- and off-peak futures prices, with more than a \$15/MWh swing between the lowest-priced months and the highest-priced months for each contract. Both the on- and off-peak curves display elevated prices in the winter and summer, peaking in January and July, respectively; the winter spike is more pronounced than the summer spike in each curve. Such seasonality in electricity prices can be a key driver of value and/or risk for renewable PPAs. Additionally, there is a slight but noticeable downward trend in prices over the PPA settlement horizon, with October on-peak prices dropping almost $5 through 2022. While the downward trend may be subtle, it does reflect a market expectation that electricity prices will remain relatively stable; this expectation is essential to incorporate into any long-term PPA value and risk analysis.

Finally, it is apparent that January 2018 futures prices are much higher than January prices in all other years. This is because extremely cold weather in the northeastern U.S. caused by a "bomb cyclone" at the beginning of January 2018 placed great strain on the natural gas supply system, resulting in gas and power prices that were elevated well-above-normal levels. The high January 2018 prices in Figure 5 show the continued effects of the early-month strain on the balance-of-month power contract. Since the extreme cold was such a rare winter weather event, it was not expected to be repeated in subsequent years; accordingly, futures prices in 2019 and beyond reflected a more normal winter outlook.

Figure 5
Forward Curve for PJM Western Hub On- and Off-Peak Power, as Quoted on January 12, 2018



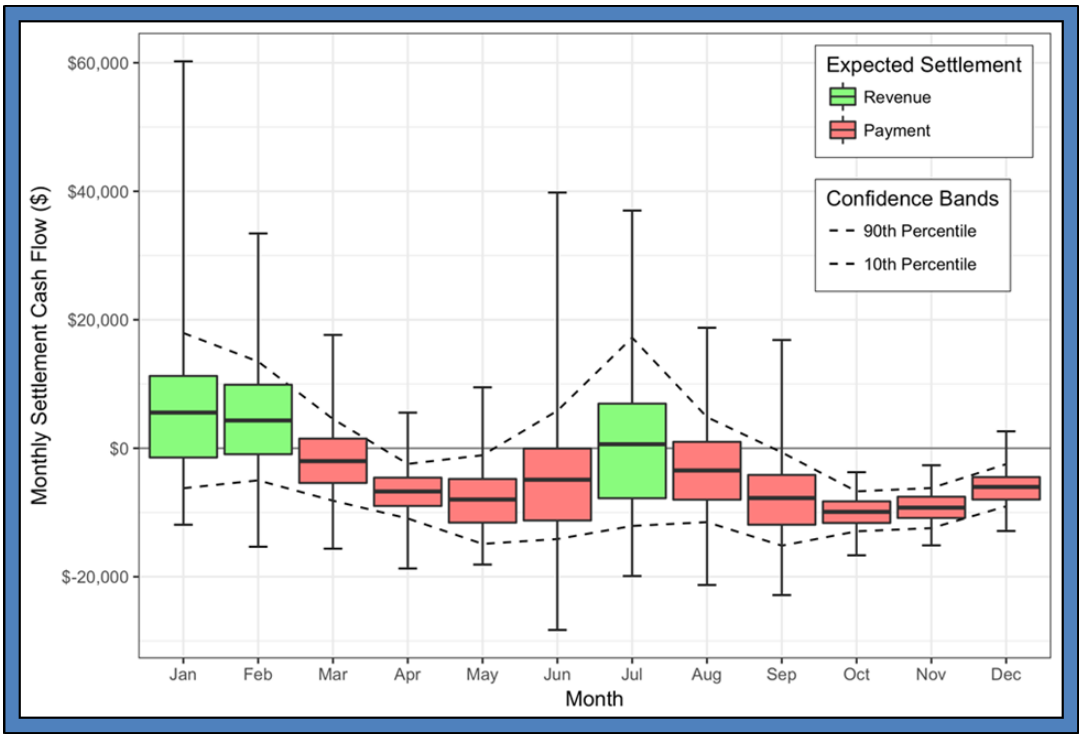
Computing Monthly Settlement Amounts and Understanding Risk

Aligning the Monte Carlo simulations of hourly renewable generation and hourly real-time electricity spot prices by simulation path and hour, we compute the hourly simulated value of electricity generated over the PPA horizon. For each simulation path, we sum the hourly generation in each month to compute the total monthly generation (TMG) in MWh, and we sum the hourly value of electricity (hourly generation in MWh times hourly price in $/MWh) in each month to compute the total monthly value of electricity (TMVE) in dollars. Denoting the contracted PPA price by K, we compute the simulated monthly settlement amount (MSA) for each simulation i and month j according to the following formula:

$$MSA_{i,j} = TMVE_{i,j} - TMG_{i,j} \cdot K.$$

Figure 6 shows box-and-whisker plots for the simulated distributions of MSAs for the solar VPPA case study in the year 2022. The horizontal black bar in each box represents the expected MSA for that month, and the boxes are colored according to whether the MSA is expected to be a revenue or a payment. At a contracted price of $35/MWh, the figure shows that the VPPA is expected to be out of the money, on average, in most months of the year.

Figure 6
Simulated CFD Monthly Settlement Amounts for 2022, Assuming a $35/MWh Contracted PPA Price



Note: Statistics displayed in the boxplots are consistent with the convention described in the caption of Figure 2.

As seen in the figure, the seasonal pattern in expected MSAs roughly follows the seasonality of the forward curve: on average, settlement amounts are greatest in the winter and summer and dip lower in the shoulder months. While simulated PPA value is actually driven by the simulated hourly spot electricity prices in each month rather than the forward curves themselves, solar generation tends to be highly coincident with diurnal patterns in hourly spot prices. Generally, both generation and prices are highest in the afternoon and lowest during the nighttime and early morning hours. Hourly price shapes do also play a role in determining PPA value, but the high degree of coincidence between solar generation and price creates alignment between the forward curve and expected PPA settlement amounts. By contrast, wind generation tends to be far less coincident with hourly price shapes, often peaking at night or in the early morning. Were this PPA contracted on a wind resource, hourly alignment between the diurnal wind generation profile and the hourly price shape profile for each month would likely play a larger role in determining expected MSA over the life of the agreement.

Figure 6 does display the influence of hourly price shapes and hourly price variability on the degree of uncertainty around expected MSAs. Seasonal differences in uncertainty around the expected MSA cannot be understood by an analysis of futures prices alone; a meaningful analysis of uncertainty and risk requires a simulation-based approach that captures location-specific trends in hourly prices and generation across a range of time scales. Electricity spot prices for PJM Western Hub tend to be most volatile in the winter and summer due to constraints on the electric transmission system and the natural gas supply system when customer load is highest. As seen in Figure 6, it is these same times of year when uncertainty in the MSA is highest, evidenced by the long whiskers on the boxplots for summer and winter months.

Importantly, in the summer months, high solar generation volumes tend to magnify the up- and down-side risks associated with uncertainty in electricity spot prices. In particular, when market prices are low, high solar generation levels will exacerbate the effect of these low prices on PPA settlement amounts, magnifying the loss the buyer must take. The contribution hourly price uncertainty makes to MSAs is evidenced in Figure 6 by the taller boxes (encompassing the P25-P75 interquartile range) and the longer whiskers (ranging from the minimum to maximum simulated MSAs) in the summer and winter, which is precisely when uncertainty in hourly electricity prices is highest.

One dynamic that is a growing concern to the renewable energy value proposition is that large quantities of renewable generation may actually exert downward pressure on market prices in real-time. We refer to this as renewable penetration risk, and it can be worsened as new renewable resources come online. For instance, high levels of mid-day solar generation in California can reduce the load net of renewables so significantly that market prices actually become negative at times, signaling oversupply of energy. This oversupply dynamic was forecasted by the California Independent System Operator back in 2013 with the iconic “Duck Curve” chart shown in Figure 1. Analogously, renewable generation oversupply occurs frequently in western Texas, where high levels of wind generation can cause congestion. Congestion is an effect in the local transmission system whereby physical constraints prevent generated electricity from reaching the point of customer demand where it is ultimately consumed. Congestion can often result in significantly negative real-time marginal electricity prices.

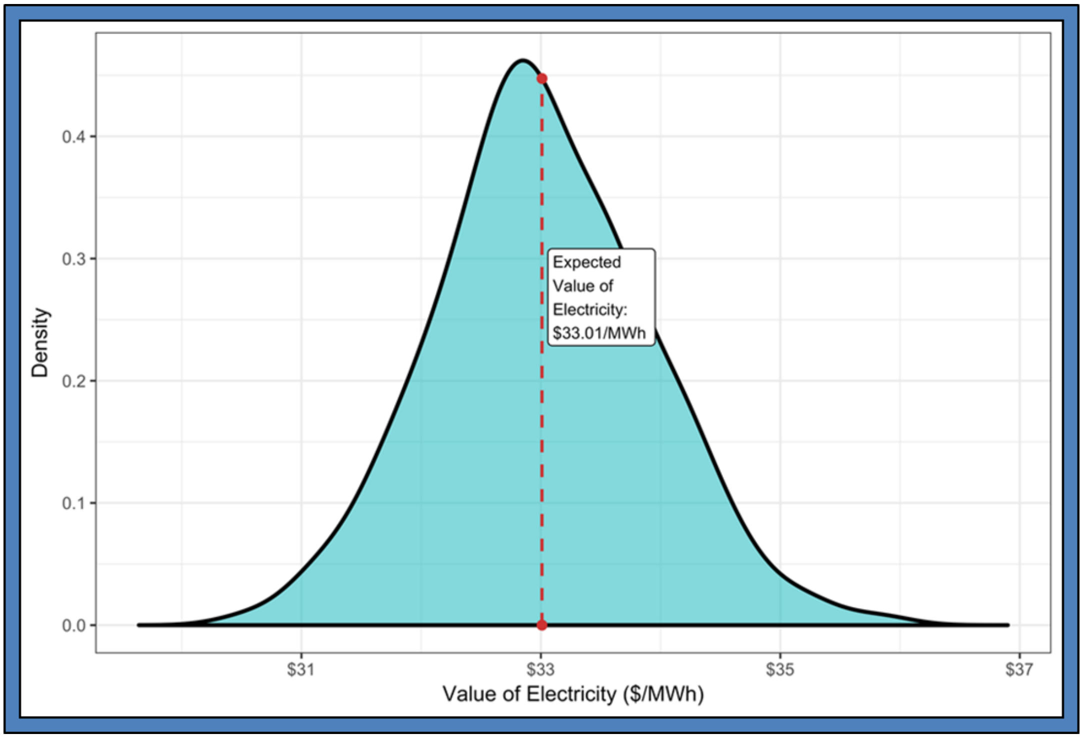
This dynamic whereby intermittency and uncertainty in generation can influence electricity market prices may actually reduce the market value of that generation. As seen in Figure 2, Figure 3, and Figure 4, the variability in renewable generation can be significant across a calendar year, month, day, and hour of the day, and the risk of variability in generation can affect the value of the overall PPA. The amount of generation that fluctuates around the anticipated mean level and the relationship of the fluctuations to the actual price of electricity together comprise the concept of “swing risk”.

Essentially, swing risk is the idea that the overall value of intermittent generation decreases when periods of high generation align with periods of low prices and periods of low generation align with periods of high prices. When this occurs, the resulting production-weighted average value of generation becomes depressed compared to what the forward curve or even the expected hourly shapes of generation and price would suggest. The phenomenon is fundamentally driven by uncertainty around the expected value. Thus, valuing a PPA by focusing on monthly forward prices or expected hourly price and generation shapes misses the swing risk dynamic entirely. To properly assess swing risk, one must use a simulation-based approach that reflects the statistical properties of when swings in both generation and production are likely to occur. In the case study analysis presented here, our simulations of generation and price at the hourly level form the basis on which we build up overall PPA value. Building aggregate PPA value from granular hourly generation and coincident market prices allows our analysis to capture and value the swing risk associated with the particular facility location and PPA settlement hub. It is critical to account for swing risk and potential renewable penetration risk for an accurate determination of PPA fair market value.

Computing Overall PPA Value

Finally, by aggregating the simulated real-time value of renewable generation over the entire settlement term, we compute the average value of electricity generated over the life of the PPA. Our simulation-based approach yields not only a point estimate for the average value of electricity, but also a range of possible outcomes based on plausible future generation and market scenarios. Each outcome is associated with a probability of occurrence based on current forward market expectations and historical trends in hourly generation and prices. Figure 7 shows the distribution of simulated average values of electricity produced over the PPA settlement term. Values range from roughly \$30 to \$36/MWh, with an expected value of \$33.01/MWh. Computing the overall value of electricity provides a high-level view of the PPA that reflects current forward market expectations about the future price of electricity, location-specific statistical trends in generation intermittency at the seasonal and hourly level, and the interplay between uncertainty in hourly generation and hourly electricity prices. The expected value of \$33.01/MWh suggests that, given current market expectations, the assumed PPA price of \$35/MWh is likely on the high-end of what the buyer could hope to recover over the life of the contract.

Figure 7
Simulated Value of Electricity Generated Over the Full VPPA Settlement Term



It is important to note that this distribution of value reflects forward market expectations as of January 12, 2018, the date when the futures contract quotes were obtained. As market conditions evolve, forward curves can move significantly, which in turn changes the expected valuation of any long-term PPA contract. Because the seasonal shape of the forward curve may change in addition to the absolute price level, the effect of forward market shifts on PPA value is highly nonlinear. The best way to track value over time is to periodically perform an analysis like that presented in this case study, based on updated forward market quotes as they become available. Such an analysis effectively serves as a "mark-to-market" process for the PPA and can be of great help to provide early warning signs when market conditions become adverse to previously contracted PPAs. Periodic tracking of PPA value, even after the contract is signed, can reveal changes in value over time and help to identify targeted active management strategies to mitigate risk and safeguard value into the future. Such risk-mitigation strategies are the subject of the second article in this two-part series, to be published in the Winter 2018 edition of the *GCARD*.

Conclusions

Renewable PPAs can be excellent vehicles for making progress toward corporate sustainability mandates, offsetting carbon emissions, and enabling claims of additionality. However, they are complex long-term financial contracts and should be treated as such within any buyer's broader business portfolio. In this first article of a two-part series on renewable PPA analytics, we illustrated how nuanced interactions between intermittent generation and electricity market prices can significantly impact PPA value. Without proper value tracking and active management, adverse market moves can erode PPA value over time and potentially require the buyer to make settlement payments each month to cover losses on the contract.

Additionally, we discussed how renewable penetration risk, production swing risk, and general market price volatility all present challenges to PPA buyers. A strategy that monitors PPA value by periodically performing a "mark-to-market" valuation of the agreement as forward prices evolve can help provide early warning signs of value erosion. Furthermore, such a periodic assessment can identify key contract-specific risks and inform targeted risk-mitigation strategies that help lock in the value envisioned at the time of contract signing.

In the second article of the series, we will elaborate on the mechanics of such risk-mitigation strategies. As a concrete example, we will build on the case study above, presenting specific strategies to protect PPA value amid volatile and ever-changing energy markets.

Endnotes

1 In theory, the VPPA structure can accommodate other forms of generation as well, though wind and solar are by far the most prevalent.

2 At the time this article was published, the real-time market cap for the Electric Reliability Council of Texas (ERCOT) was $9000 per MWh. Locational marginal prices for electricity realized this cap on two separate real-time intervals in January of 2018 during a period of exceptionally cold weather.

3 Negative marginal prices for electricity are indications that the grid is oversupplied. Such negative pricing can be quite common in areas with high renewable penetration. For instance, negative prices are common in western Texas during windy conditions, when the large amount of local wind generation can oversupply the comparatively small electricity demand in the region.

4 Unit-contingent contracting means the buyer agrees to take the energy as-produced from the facility. Such contracts may or may not include monthly or annual production guarantees.

5 Image credit: https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

6 https://en.wikipedia.org/wiki/Nesquehoning,_Pennsylvania.

7 Historical solar radiation data is publicly available from the National Solar Radiation Database. See https://nsrdb.nrel.gov/ for details.

8 See https://sam.nrel.gov/ for details.

9 The assumption that future renewable generation from the facility will reflect similar statistical attributes to historical generation explicitly ignores potential long-term climate trends. In theory, significant change in average rainfall, average temperature, or other weather-related variables at the monthly level could significantly affect renewable facility generation. However, such climate trends are extremely difficult to forecast accurately, and any such treatment was considered outside the scope of the present analysis.

10 On- and off-peak period definitions vary by region. For products that deliver energy within the PJM regional transmission organization, on-peak hours are defined to be Monday through Friday from hour-ending 0800 through hour-ending 2300 eastern prevailing time, with all other hours defined to be off-peak.

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This article was prepared by the authors in their personal capacity. The opinions expressed in this article are the authors' own and do not reflect the view of the authors' employers or of the University of Colorado Denver Business School.

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Mr. Lance Titus currently serves as Managing Director at Uniper Global Commodities. He has over twenty years of commodities trading, structuring and risk management experience. He has held senior leadership roles from Wall Street to the energy industry, working for an investment bank as well as for leading utilities, unregulated entities and merchant energy firms. He has transacted in over $15 Billion in trading and originated structured transactions in the energy and environmental commodity markets with a sector focus in electricity, natural gas, renewables, carbon and emissions. Mr. Titus has been a featured panelist at Bloomberg's "The Future of Energy Summit" in New York, and also as a lecturer for the course, "Foundations of Commodities," at the University of Colorado Denver.

Mr. Titus holds an M.B.A. from the Daniels College of Business at the University of Denver and a B.S. in Finance and Marketing from Clarion University. He serves on the Advisory Board of cQuant.io and is a member of the J.P. Morgan Center for Commodities' Research Council as well as its Advisory Council. In addition, he serves as a member of the *Global Commodities Applied Research Digest*'s Editorial Advisory Board.

International Commodities Symposium Summary

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Over 80 international commodities researchers and practitioners attended the J.P. Morgan Center for Commodities' (JPMCC's) inaugural "New Directions in Commodities Research" international symposium in August 2017 to discuss critical thinking and new research related to commodities. The 2017 symposium took the place of the JPMCC's annual Research Council meeting. Professor Graham Davis, Ph.D., of the Colorado School of Mines co-organized the conference with Dr. Ajeyo Banerjee, Ph.D., of the University of Colorado Denver Business School. The agenda for the conference included keynote speakers, speaker sessions organized by academic and practitioner members of the Center's Research Council, and competitive academic sessions selected by the conference's Technical Committee consisting of Research Council members and which was chaired by Professor Davis. There were two concurrent sessions throughout the symposium. The conference's lead sponsor was the CME Group Foundation. The conference also benefitted from sponsorship by the Payne Institute for Earth Resources and the Chartered Alternative Investment Association (CAIA).

The 2017 symposium had speakers and participants from a broad set of industries, regulatory agencies, and research institutions, including oil and natural gas companies, automobile manufacturers, renewable energy companies, U.S. national laboratories, universities, the Federal Reserve Bank, the Commodity Futures Trading Commission, financial institutions, exchanges, and market research institutions. The broad range of topics covered by the conference included renewable energy finance, raw materials, shipping finance, macroeconomics, and China's economic supply side reform.

We are fortunate that three of the conference's presenters have summarized their 2017 presentations for the *GCARD*. In the Winter 2017 issue, Ms. Jodie Gunzberg, CFA, summarized her presentation on "Chinese Economic Growth and Commodity Performance." Ms. Gunzberg is Managing Director and Head of U.S. Equities at S&P Dow Jones Indices and also serves a member of the *GCARD*'s Editorial Advisory Board. In the current issue of the *GCARD*, Professor Lutz Kilian, Ph.D., of the University of Michigan, Ann Arbor, co-authored an article based on his keynote presentation on oil prices and the economy; Professor Kilian's *GCARD* article is entitled, "Why Did the 2014-16 Oil Price Decline Not Create a Surge in Economic Activity?" He is also a member of the JPMCC's Research Council. Also, in this issue of the *GCARD*, Dr. Martin Stuermer, Ph.D., of the Federal Reserve Bank of Dallas summarized his symposium lecture on commodity price booms and busts; Dr. Stuermer's *GCARD* article is entitled, "Demand Shocks Fuel Commodity Price Booms and Busts."

In this report, we successively summarize four additional presentations from the August 2017 conference.

"Commotion, Complexity and Competition: Interesting Times in the Rare Earth Business"

Dr. Alex King, Ph.D., Director of the Critical Materials Institute (CMI) in Ames, Iowa, opened the conference with a discussion of rare earth metals, which are critical materials that have national security implications and which are an often overlooked area of research in commodities. The CMI researches technical methods to extract, refine, and separate rare earth metals from each other. Demand for rare earth elements continues to increase with use in cell phones, hard drives, head phones, LEDs, CFLs, televisions and in magnets used in electric vehicles. The importance of rare earth elements has even been used as plotlines in novels and television series. China is the world's largest exporter while Japan is the largest importer. Prices are volatile, rising by a factor of 7 from 2008 to 2011 only to fall to just twice the original price by 2014. Dr. King noted that the name, "rare earth" elements, is misleading. These elements are actually quite abundant, but seem rare as the concentration of these elements is far more dispersed while metals such as lead and nickel have more concentrated deposits. Dr. King outlined several of the factors contributing to the uncertainties in the market, including problems in price discovery due to the absence of organized markets, the Chinese monopoly in supply, and political conflicts.

Dr. Alex King, Ph.D., Director of the Critical Materials Institute, was a keynote speaker at the JPMCC's international commodities symposium, which was held at the University of Colorado Denver Business School on August 10 through August 11, 2017.

"Public Policy Trends and Commodity Market Impacts"

Dr. Christopher Hansen, Ph.D., discussed renewable energy policy and development during the conference. Dr. Hansen is a member of the Colorado General Assembly. He noted the recent decline in the cost of installing new wind power and solar power generation capacity. The renewable energy industry may soon be able to be cost competitive with other forms of energy, even if government subsidies are reduced, he predicted. Dr. Hansen also discussed the potential for self-driving vehicles to become mainstream in the next 5 to 10 years, which would thereby have a revolutionary impact on traffic and highway infrastructure.

Dr. Christopher Hansen, Ph.D., and member of the Colorado General Assembly, discussed renewable energies during his presentation at the JPMCC's August 2017 international commodities symposium.

"Distributed Ledger Technology and the Future of Financial Markets"

The rapid development of Blockchain and Bitcoin has led to the discussion of financial technology and cryptocurrencies in commodity circles. During the conference, Mr. Garth Leonard, Director & Co-Head of Commodity Tracker at IHS Markit, and Mr. Jeffrey Billingham, (then) Vice President at IHS Markit, considered the impact of distributed computing and data storage on the future of the financial markets with the possibility that trading may become less concentrated on large financial exchanges, and scattered across thousands of servers around the world. While media attention focuses on Bitcoin, Blockchain technology is likely to be more transformative to the global economy, including faster clearing of securities transactions. Smart contracts for financial derivatives may make International

Swaps and Derivatives Association (ISDA) agreements and slow clearing of Over-the-Counter (OTC) derivative transactions relics of the past. In commodities, Blockchain technology can digitize receipts and bills of lading, leading to faster shipping times and potentially safer financing of commodities by preventing the unsavory practice of pledging commodity collateral to multiple lenders.

Mr. Garth Leonard, Director & Co-Head of Commodity Tracker at IHS Markit, explained Digital Ledger Technology during his presentation at the JPMCC's August 2017 international commodities symposium.

"China: Credit, Collateral, and Commodity Prices"

Dr. Keith Black, Ph.D., CFA, CAIA, discussed China's credit cycle in connection with changes in demand for commodities. Dr. Black is Managing Director, Curriculum and Exams, at the Chartered Alternative Investment Analyst Association. He also serves as a member of the *GCARD*'s Editorial Advisory Board. Dr. Black had previously written on his presentation topic in an article in the Fall 2016 issue of the *GCARD*. In his lecture, Dr. Black analyzed the use of industrial metals as collateral for loans to Chinese companies and traders. The demand for metals, especially copper, can be influenced by both industrial demand as well as the demand for collateral for financing transactions. Investors need to be aware that not all industrial metals imported by China are immediately used for industrial purposes, but can be warehoused and later returned as supply to the commodity markets. Thus, credit cycles, interest rates and credit conditions can all impact the market for industrial metals.

Dr. Keith Black (standing), Ph.D., CFA, CAIA, discussed his *GCARD* research digest article during his presentation at the JPMCC's August 2017 international commodities symposium. To Mr. Black's left are his fellow speakers on the conference's Chinese commodity demand panel. From left-to-right are Ms. Jodie Gunzberg, CFA, Managing Director and Head of U.S. Equities, S&P Dow Jones Indices; and Dr. Kaifeng (Kevin) Chen, Ph.D., Chief Strategist, Hywin Capital Management, LLC. Each of the panel's speakers are members of the *GCARD*'s Editorial Advisory Board.

Conclusion

Building on the success of the 2017 conference, Professor Jian Yang, Ph.D., CFA, is organizing the JPMCC's second commodities symposium for August of this year, as discussed in his article, "Update from the Research Director of the J.P. Morgan Center for Commodities," which is also in this issue of the *GCARD*. We welcome *GCARD* readers to consider registering for this conference!

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Dr. Kaifeng (Kevin) Chen is the Chief Strategist for Hywin Capital Management, LLC. Dr. Chen received a B.A. degree in Economics from the Renmin University (China) and a Ph.D. in Finance from the Financial Asset Management Engineering Center at the University of Lausanne (Switzerland). He is also an Adjunct Assistant Professor at New York University and a member of the Economic Club of New York. Dr. Chen started his career at the China Development Bank, after which he became a Director of Asset Allocation at Morgan Stanley and a Senior Portfolio Manager, Credit Agricole in Amundi Asset Management. As an expert in economics and finance, he has been interviewed by many media outlets such as CCTV, *China Security Journal*, Xinhua News Agency, *21st Century Business Herald*, Tencent Finance and Sina Finance.

KEITH BLACK, Ph.D., CFA, CAIA
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Dr. Keith Black has over twenty-five years of financial market experience, serving approximately half of that time as an academic and half as a trader and consultant to institutional investors. He currently serves as Managing Director of Curriculum and Exams for the CAIA Association. During his most recent role at Ennis Knupp + Associates, Dr. Black advised foundations, endowments and pension funds on their asset allocation and manager selection strategies in hedge funds, commodities, and managed futures. His prior experience includes commodities derivatives trading, stock options research and CBOE floor trading, and building quantitative stock selection models for mutual funds and hedge funds. Dr. Black previously served as an assistant professor and senior lecturer at the Illinois Institute of Technology.

He contributes regularly to *The CFA Digest* and has published in the *Journal of Wealth Management*, the *Journal of Trading*, the *Journal of Investing*, and the *Journal of Alternative Investments*, among others. He is the author of the book, Managing a Hedge Fund, as well as the co-author of the 2012 and 2015/2016 second and third editions of the CAIA Level I and Level II textbooks. Dr. Black was named to the *Institutional Investor Magazine*'s list of "Rising Stars of Hedge Funds" in 2010.

Dr. Black earned a B.A. from Whittier College, an M.B.A. for Carnegie Mellon University, and a Ph.D. from the Illinois Institute of Technology. He has earned the Chartered Financial Analyst (CFA) designation and was a member of the inaugural class of the Chartered Alternative Investment Analyst (CAIA) candidates.

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Why Did the 2014-16 Oil Price Decline Not Create a Surge in Economic Activity?

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Xiaoqing Zhou, Ph.D.
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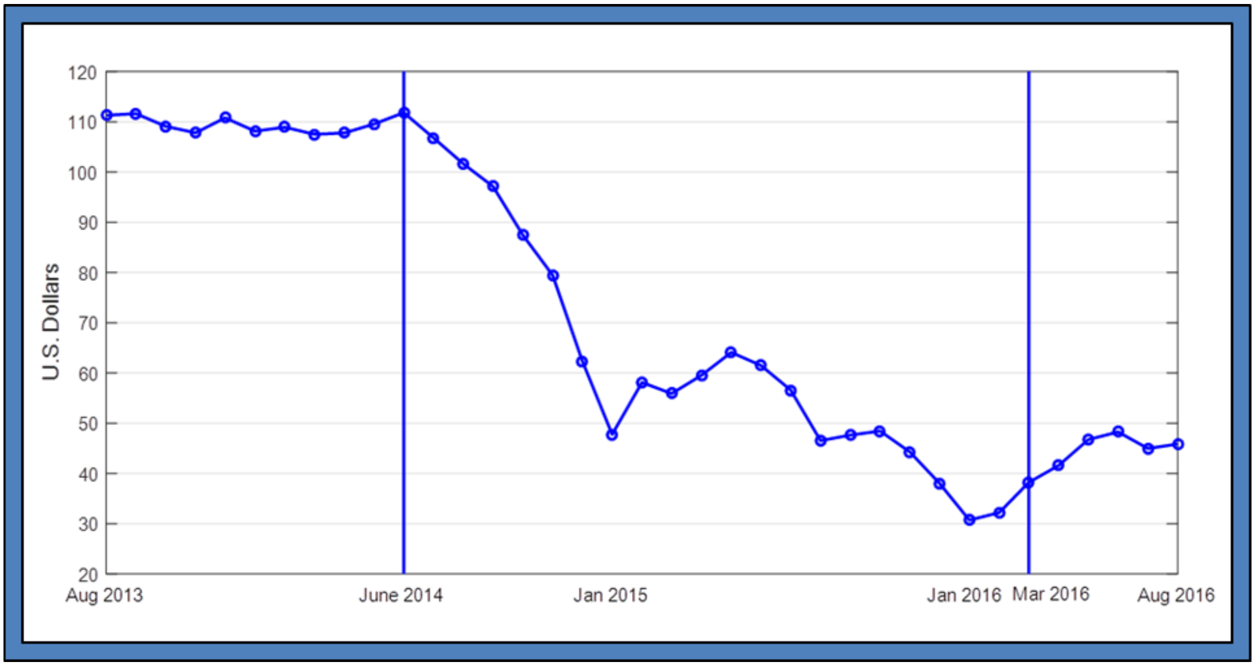
Professor Lutz Kilian (microphone), Ph.D., University of Michigan, Ann Arbor, and member of the J.P. Morgan Center for Commodities' (JPMCC's) Research Council, participating in the JPMCC's inaugural Research Council meeting at the University of Colorado Denver Business School on April 18, 2015.

Introduction

Between June 2014 and March 2016, the inflation-adjusted price of oil dropped by 66% (see Figure 1). This price decline was one of the largest in history, yet average U.S. economic growth accelerated only slightly from 1.8% at annual rates before the oil price decline to 2.2% after the oil price decline (see Table 1). The absence of an economic boom in response to falling oil prices has puzzled some observers, given that higher oil prices in the past have been blamed for major economic recessions.

Given the growing consensus in the academic literature that unexpected oil price increases tend to have only modest effects on U.S. economic growth, however, it would be surprising, if an unexpected decline in the price of oil had large stimulating effects on the economy (see Kilian, 2008). Indeed, recent research shows that the sluggish response of U.S. real GDP growth to unexpectedly lower oil prices is exactly what standard economic models that emphasize the effects of oil price shocks on consumer and business spending would have predicted (see Baumeister and Kilian, 2017; Baumeister, Kilian and Zhou, 2017).

Figure 1
Price per Barrel of Brent Crude Oil



Are Oil Price Shocks Demand or Cost Shocks for the U.S. Economy?

A time-honored view has been that lower oil prices stimulate the economy by lowering the cost of producing domestic goods and services. Outside of the refining sector, however, there are few industries that heavily depend on crude oil or oil products as a factor of production, casting doubt on the empirical relevance of this channel. If there is any sector of the economy that should directly benefit from lower prices through this cost channel, it would have to be the transportation sector; yet data for truck freight, rail freight and air transportation volumes show no evidence at all of growth in the U.S. transportation sector accelerating after the 2014 oil price decline.

In fact, the stock returns for industries that rely on oil or oil products in production (such as chemicals or rubber and plastics) increased only slightly more than the average U.S. stock return after June 2014, if at all. Thus, there is no evidence that the cost channel of transmission is important for the U.S. economy.

In contrast, the stock returns of industries whose demand depends on the price of oil (such as tourism and retail sales) have been far above average stock returns. This evidence supports the alternative (and by now widely accepted) view that the primary channel of the transmission of unexpected oil price declines is higher demand for domestic goods and services (see Lee and Ni, 2002; Edelstein and Kilian, 2009; Hamilton, 2013). For example, consumers faced with a windfall gain in income caused by unexpectedly low gasoline prices will spend most of this extra income, stimulating economic growth via a Keynesian multiplier effect. This demand channel of transmission is crucial for understanding what happened after June 2014.

The Demand Channel of Transmission

Changes in the real price of gasoline affect the purchasing power of U.S. consumers to the extent that consumers spend their income on gasoline produced from imported crude oil. As the price of crude oil decreases, so does the price of gasoline.[1] Because the demand elasticity for gasoline is smaller than one, this means that consumers effectively spend less income on imported crude oil than before the gasoline price decline. Thus, they are collectively able to spend more on domestically produced goods and services. If there is slack in the economy, this increase in domestic demand, all else equal, raises real GDP.

Unexpected oil price declines may also increase business investment spending. Domestic firms have an incentive to invest, as consumer demand for goods and services increases in response to lower oil prices. Their spending adds to the overall stimulus for the U.S. economy.

This demand channel of transmission is well documented in the literature. Recently, there has been some debate about whether lower gasoline prices may have failed to stimulate domestic spending this time because of structural changes in the transmission of oil price shocks to consumer spending. It can be shown that these concerns are unfounded.

Has the Effect of Oil Price Shocks on Consumer Spending Changed Since the 2000s?

One concern has been that the decline in the price of oil may not have been passed on to retail motor fuel prices, but the data show that these cost savings were fully passed on by refiners and gasoline distributors. Another conjecture has been that consumers, unlike in the past, chose to pay back credit card debt or to increase their savings rather than spending their extra income, but this hypothesis is not supported by the data either. Nor is there support for the notion that increased uncertainty about gasoline prices has depressed automobile demand, slowing overall consumption growth.

In fact, there was a notable increase in private consumption after June 2014. As Table 1 shows, average real consumption growth accelerated from an average annual rate of 1.9% to 2.9% during 2014Q3-2016Q1. Given that private consumption alone accounts for about 70% of real GDP, this increased consumption growth, all else equal, implies a substantial increase in U.S. real GDP growth.

Table 1
Average Growth at Annual Rates in U.S. Real GDP and some of its Components (Percent)

	2012Q1-2014Q2	2014Q3-2016Q1
Real GDP	1.8	2.2
Private Consumption	1.9	2.9
Nonresidential Investment	5.1	1.5
Oil-Related Investment	7.2	-48.2
Non-Oil Related Investment	4.9	4.6
Exports	3.2	0.7
Imports	2.3	2.9

Note: Oil-related investment includes investment in petroleum and natural gas structures as well as mining and oil field machinery.

Why U.S. Real GDP Growth Remained Sluggish

Why then did U.S. real GDP growth remain so sluggish? Given that the United States produces about half of the crude oil that it consumes, it is not enough to focus on the spending by consumers and by firms satisfying the demand of consumers. The overall change in spending also reflects the response of domestic oil producers to lower oil prices. As Table 1 shows, there was a dramatic drop in nonresidential investment by the oil sector after June 2014, which largely offset the increase in private consumption growth, lowering average real GDP growth to 2.2% at annual rates.

This type of oil investment response is by no means unprecedented. For example, the sharp decline in the price of oil in 1986 resulted in an increase in private consumption and a decline in oil-related nonresidential investment much like that in 2014-16 (see Edelstein and Kilian, 2007).

Did the U.S. Shale Oil Revolution Alter the Transmission of Oil Price Shocks?

A common concern is that there may have been a structural break in the transmission of oil price shocks because of the increased importance of the oil sector for the U.S. economy since about 2011. Much has been made of the increased importance of the shale oil sector, in particular, for understanding the effects of the recent oil price decline on the U.S. economy.

Shale oil (also known as tight oil) refers to crude oil extracted from nonpermeable rock formations by means of horizontal drilling and fracking. Since this new extraction technology was introduced in the late 2000s, U.S. shale oil production has surged, reversing the long-run decline in U.S. crude oil production since the 1970s (see Kilian, 2016; 2017). When the price of oil fell after June 2014, the shale oil industry came under increasing financial pressure. Shale oil producers responded by cutting costs and increasing efficiency on an unprecedented scale.

One argument that increased shale oil production may have changed the transmission of oil price shocks focuses on the banking sector. Many shale oil producers received loans from U.S. banks before the oil price decline, with oil deposits below the ground serving as collateral. The value of this collateral sharply declined after June 2014, making these loans riskier than anticipated by the banks. It has been suggested that oil loans going bad may have caused fears of contagion in the banking sector, not unlike the mortgage loans held by banks during the housing and financial crisis of 2008, undermining financial intermediation and explaining the absence of an economic boom. There is no empirical support for this view, however. In fact, the exposure of banks to the oil sector loans is much smaller than their exposure to mortgage loans prior to the financial crisis, and bank stocks continued to rise long after the 2014 oil price decline.

Given the growth in the U.S. oil sector caused by the shale oil revolution, it has also been argued that declines in investments by the oil sector may have spilled over to investment expenditures in other sectors of the economy, causing a ripple-effect across the economy. For example, lower demand for oil equipment may cause investment in the steel sector to decline. There is no apparent co-movement in investment spending across sectors, however. Nor is there theoretical or empirical support for the notion that oil investment has become more sensitive to oil price fluctuations.

There is evidence that the recent oil price decline, unlike earlier oil price declines, was not associated with increased petroleum imports, given the plentiful supply of shale oil in the United States. The latter effect, however, is not only small, but it implies higher rather than lower real GDP growth and hence cannot explain the observed sluggish growth.

Thus, the sluggish response of U.S. economic growth is not the result of a structural break caused by the shale oil boom. This does not mean that the U.S. shale oil boom did not matter for the response of the U.S. economy, of course. Clearly, without this boom, the share of oil and gas extraction in GDP, which in 2014 was almost the same as in 1985, would have been much lower and the sharp decline in oil-related investment would have mattered less for U.S. real GDP growth.

Did the Recent Decline in the Oil Sector Affect the Economy More Broadly?

Yet another argument for slower economic growth has been that frictions in reallocating workers from the oil sector to other sectors may have caused higher U.S. unemployment. This view is not only hard to reconcile with the continued rapid decline in the overall U.S. unemployment rate, but there is also evidence that even in most oil-producing states (such as Texas, New Mexico or Oklahoma) the unemployment rate declined from June 2014 to March 2016, and that these declines cannot be explained simply by migration away from oil-producing states. For example, the unemployment rate in Texas dropped by 0.8 percentage points and the number of unemployed in Texas declined, while the labor force and the number of employed increased. In fact, in five of the seven most important oil-producing states the unemployment rate declined. Even in North Dakota, one of the states hardest hit by lower oil prices, the unemployment rate only increased from 2.7% to 3.1% in the seven quarters after the oil price decline. We conclude that there is no evidence of frictions preventing the reallocation of labor used in oil production.

It is also possible, of course, that there are frictions that prevent the reallocation of the capital employed in producing oil. The number of oil rigs, for example, in early 2016 had declined by 75% relative to its peak in October 2014. Many of these rigs are sitting unused in storage facilities, suggesting considerable underutilization of capital. Likewise, petroleum rail car loads declined by 30% after September 2014. To the extent that this capital is no longer used, one would expect the value added by the U.S. economy to decline by construction. In fact, the underutilization of capital in oil-producing states such as North Dakota goes much further than the oil sector narrowly defined. It includes motels that are no longer occupied, local bars that are empty, and local stores without customers, for example. It is difficult to quantify the loss in real GDP caused by this widespread underutilization of capital in oil-producing states, but it can be shown that U.S. real GDP growth is much the same whether oil-producing states are included or excluded, suggesting that the state-level effects of underutilized capital are small enough to be ignored. Thus, we can be confident that frictions to the reallocation of capital and labor do not explain the sluggish response of the U.S. economy to lower oil prices.

The Net Stimulus

Given that there is no evidence that the transmission of oil price shocks has changed since the 2000s, one can use standard regression-based methods based on historical data to estimate the cumulative effect of lower oil prices on U.S. real GDP of changes in private consumption and non-oil business investment spending.

It is straightforward to quantify the cumulative effects of unexpected changes in consumers' purchasing power on private consumption by regression methods, accounting for changes in the dependence of the U.S. economy on imports of gasoline and crude oil. It can be shown that between June 2014 and March 2016, the consumption stimulus raised real GDP by 0.51 percentage points. The effect on non-oil business investment may be estimated in much the same way as for private consumption and accounts for an additional cumulative increase by 0.19 percentage points in U.S. real GDP.

This stimulus, however, is largely offset by a decline in real GDP of 0.57 percentage points associated with lower investment by the oil sector, resulting in a very small net stimulus of about 0.1 percentage points of average annual real GDP growth (see Table 2). This estimate is consistent with the observed small increase in average real GDP growth in Table 1. Thus, the absence of a large economic boom in response to lower oil prices is exactly what standard models of the transmission of oil price shocks based on the demand channel predict.

Table 2: The Net Stimulus from Unexpectedly Lower Real Oil Prices, 2014Q2-2016Q1

Effect on U.S. Real GDP of	Percent of Cumulative Real GDP Growth
Private Consumption	0.51
Oil-Related Private Investment	-0.57
Non-Oil Related Private Investment	0.19
Net Stimulus from Investment and Consumption	0.13

Note: All cumulative multipliers have been computed based on an import propensity of 15%.

Is This Time Different?

There are few major oil price declines in history. The episode that is arguably closest to recent events is the oil price drop that started in late 1985, when a shift in Saudi policies caused a large and sustained decline in the global price of oil that extended into 1987. Although there are a number of differences between these two episodes, it can be shown that the economic mechanisms at work in 1986-87 were very much the same as today, as was the outcome that the net stimulus from lower oil prices is effectively zero.[2]

Concluding Remarks

No one familiar with standard empirical models of the transmission of oil price shocks should have been shocked by the lackluster performance of the U.S. economy since June 2014. It is well documented that the consumption stimulus from lower oil prices is only modest, and the recent episode is no exception. Likewise, earlier studies of the large and sustained decline in the price of oil in 1986 already documented the sensitivity of U.S. oil investment to falling oil prices, so the sharp decline in oil investment after June 2014 and the implied reduction in U.S. real GDP growth should not have come as a surprise.

Nevertheless, the most recent episode has sharpened our understanding of the effects of lower oil prices on the economy. What has not been fully appreciated previously is that the oil investment response does not depend on the magnitude of the oil price decline so much, but on how far the expected oil price declines relative to the break-even point. Hence, oil investment may change disproportionately, as oil price expectations change. This fact may hold the key to understanding the macroeconomic consequences of oil price shocks in countries with a sizable oil sector such as the United States.

In contrast, when analyzing European economies without a domestic oil industry of their own, modeling oil investment is not a concern. Our analysis implies that the decline in the Brent price of crude oil, all else equal, should have a larger stimulating effect on these economies than on the U.S. economy. There are several mitigating factors, however. First, one of the determinants of lower oil prices has been a slowdown in the global economy that is likely to slow growth in export-oriented European economies more than in the United States. Second, the Euro depreciated against the U.S. dollar after June 2014, offsetting in part the decline in the dollar price of Brent crude oil. Third, given the much larger share of gasoline taxes in European retail gasoline prices, the pass-through from lower oil import prices to retail gasoline prices is much smaller, and hence the response of consumers is more muted.

Endnotes

Professor Kilian presented on this article's topic during his keynote speech at the JPMCC's August 2017 international commodity symposium, which took the place of the JPMCC's annual Research Council meeting.

The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Bank of Canada.

1 The extent of the gasoline price increase depends on the cost share of crude oil in producing gasoline.

2 One important difference is that the cumulative decline in the price of oil after June 2014 was twice as large as that in 1986, while the share of oil and gas extraction in GDP was about the same as in late 1985. At the same time, the dependence on imported oil and gasoline was much lower in 1986 compared to today. These facts together explain why the estimated response of private consumption to lower oil prices in particular was much lower in 1986. A second difference is that the oil price decline in 2014-16 was in part associated with a global economic slowdown which slowed the growth in U.S. real exports, whereas the oil price drop in 1986 was caused by political developments in the global oil market. Controlling for the global economic slowdown, U.S. real GDP growth after June 2014 would have been somewhat higher without affecting the substance of the results. Finally, the 1986 oil price decline coincided with the Tax Reform Act of 1986, which makes it difficult to disentangle the causal effects on nonresidential investment, but helps explain the disproportionately large decline in oil investment that took place in 1986.

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Demand Shocks Fuel Commodity Price Booms and Busts

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Dr. Martin Stuermer, Ph.D., Senior Research Economist, Federal Reserve Bank of Dallas, presenting on what drives commodity price booms and busts at the J.P. Morgan Center for Commodities' (JPMCC's) international commodities symposium, which was held at the University of Colorado Denver Business School from August 10, 2017 through August 11, 2017.

Booms and busts in commodity markets are a particularly important part of the global economy. They affect inflation and consumer spending, and determine investment and welfare in producing nations. They also influence growth-enhancing institutions and may even lead to civil unrest.

Understanding which shocks drive these low-frequency price movements and how long they persist is important in formulating environmental and resource policies, for the conduct of macroeconomic policy, and, most importantly, for investment decisions involving extractive and agricultural sectors of the economy.

Commodity prices are driven by shocks in supply and/or demand. For example, a commodity supply shock is an unexpected decline in crop yield due to adverse weather, which shifts the supply curve inward and increases prices.

An aggregate commodity demand shock changes the demand for all commodities at the same time. For example, China's rapid industrialization led to stronger-than-expected increases in the demand for a broad variety of commodities such as copper, oil and wheat over the past decade.[1]

Thus, examining the effects of shocks on commodity prices is an intriguing avenue of research.[2] While the literature on modeling oil markets has examined only a handful of boom-and-bust phases since the early 1970s, this analysis of commodity markets is based on a new dataset of price and output levels for 12 agricultural, metal and soft commodities for the period, 1870 to 2013.

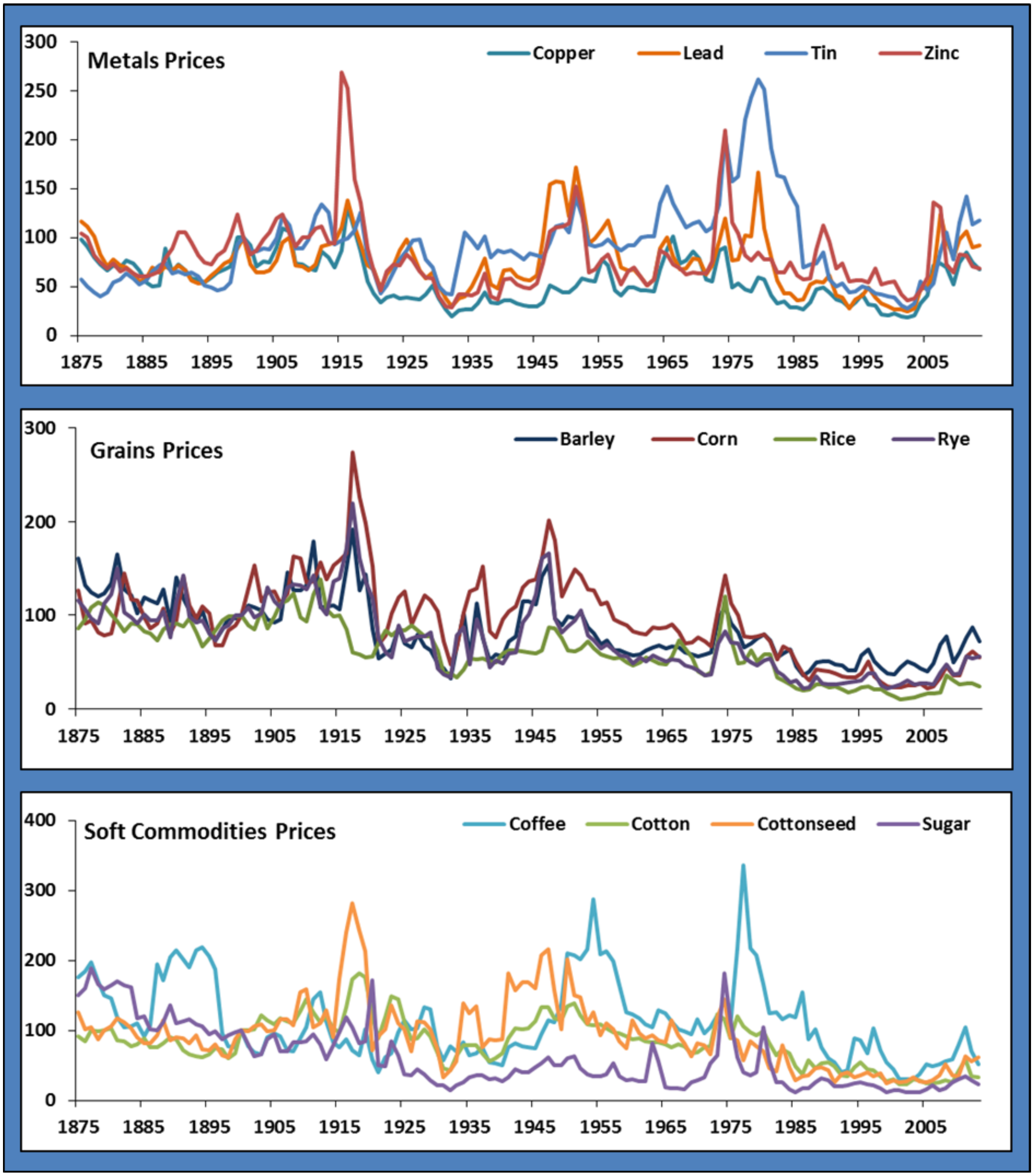
China's effect on commodity markets is not a new phenomenon. Throughout history, demand shocks due to rapid industrialization have driven commodity price booms.

Aggregate demand shocks strongly predominate over supply shocks as drivers of price booms across a broad variety of commodities. Demand shocks strongly affect prices for about 10 years, while commodity supply shocks impact prices for roughly five years. As periods of industrialization lose steam and supply catches up, busts follow. Prices return to their stable or declining trends.

Commodities Dataset Created

A dataset encompassing global output and prices for 12 commodities – barley, corn, rice, rye, coffee, cotton, cottonseed, sugar, copper, lead, tin and zinc – was assembled covering the 143-year study period (Figure 1).

Figure 1
Booms, Busts Not a New Phenomenon
Annual Real Price Indexes for 12 Commodities, 1900=100



Source: Jacks and Stuermer (2018).

The commodity markets selected exhibit characteristics that make a long-run analysis feasible. Specifically, there is longstanding evidence of an integrated world market; there is no strong indication of sudden change in how the commodity is used, and there is a high degree of product homogeneity. Thus, the 12 commodities selected have long-term characteristics that mineral commodities such as iron ore or crude oil only gained relatively recently.

Identifying Price Shocks

Shocks are unexpected shifts in the supply or demand curves of a commodity market. An underlying idea is that firms do not anticipate these shocks. Because it's not easy for supply or demand to fully respond, there are either supply shortfalls or oversupply, leading to price increases or decreases as firms discover they are either underinvested or overinvested.

The econometric model employed here allows identification of the contribution of three types of shocks to each commodity price. The "aggregate demand shock" (for example, unexpected increase in commodity demand due to rapid industrialization) is based on the assumption that this shock can trigger investment and innovation, and subsequent long-run effects on overall output.[3]

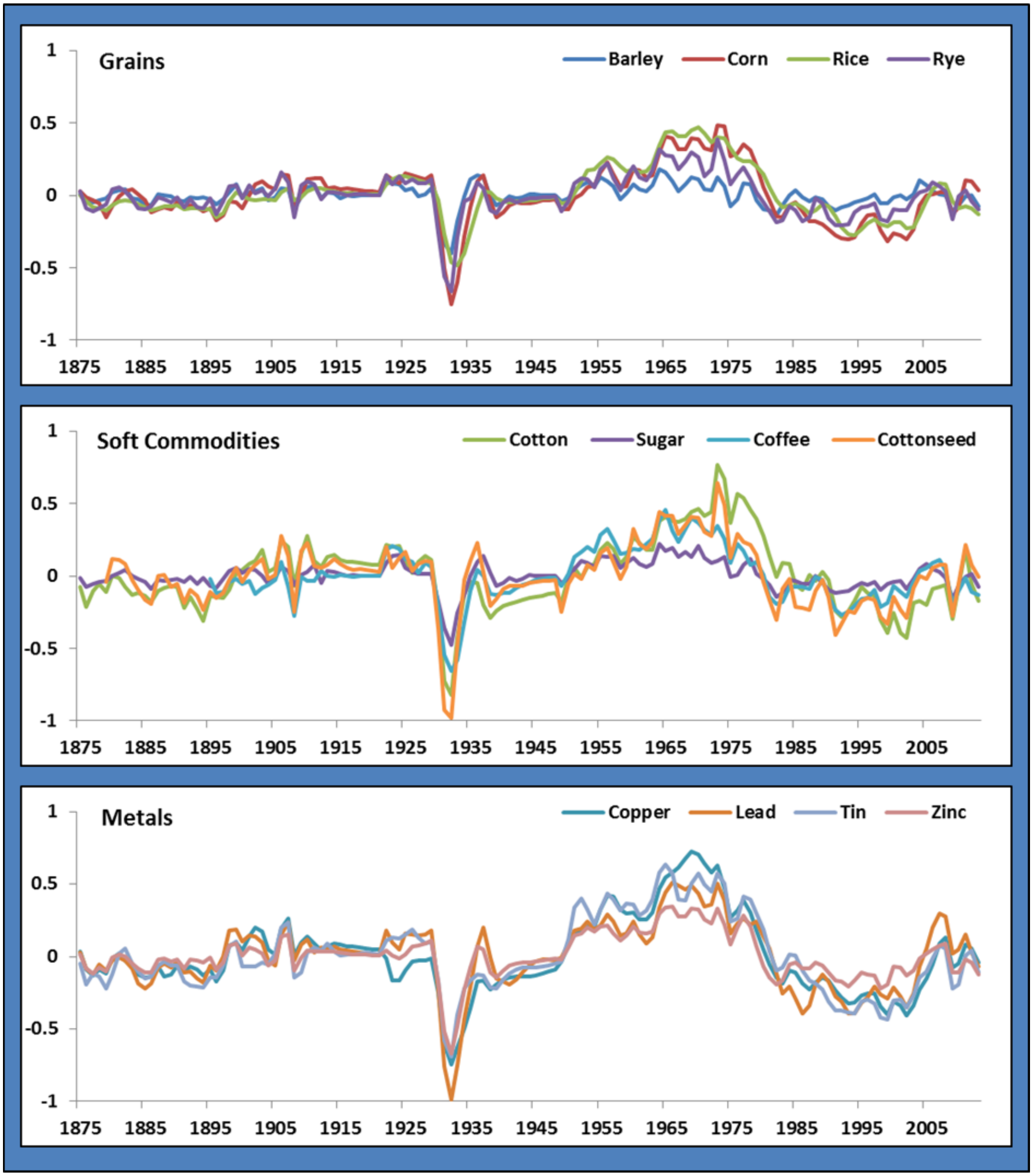
By comparison, it is assumed that a "commodity supply shock" – such as cartel action or the weather – only affects global gross domestic product (GDP) for a couple of years. This is consistent with evidence that oil supply shocks have had short-lived effects on U.S. GDP.[4]

Any residual shock – or one that isn't attributable to an aggregate shock or a commodity supply shock – is a "commodity market-specific demand shock." This type of shock is assumed to only affect capacity utilization and poses no long-run effects on global GDP or commodity production.

Booms, Busts Explained

Econometric modeling allows assessment of the contribution of each type of shock to commodity prices over time. Figure 2 represents a counterfactual simulation of what the prices of specific commodities would have been solely in the presence of aggregate commodity demand shocks.

Figure 2
Commodity Prices React to Demand Shocks Simultaneously



Source: Jacks and Stuermer (2018).

Note: Charts show a counterfactual simulation of what the prices of specific commodities would have been solely in the presence of aggregate commodity demand shocks.

The collective story that emerges suggests that although the proportional contribution of the aggregate commodity demand shocks naturally varies across the different commodities, the accumulated effects broadly follow the same pattern. Thus, while aggregate commodity demand shocks affect prices to different degrees, they affect the real commodity prices at the same time. These results then suggest that aggregate commodity demand shocks have a common source.

This interpretation of aggregate commodity demand shocks is in line with what economic history suggests about global output fluctuations. Historical decompositions start in 1875, when prices were depressed due to the negative accumulated effects of aggregate commodity demand shocks on prices during the first – but somewhat forgotten – Great Depression.

The effects of subsequent aggregate commodity demand shocks are in line with historical occurrences of business cycles in major economies. For example, the effects of the large negative aggregate commodity demand shock in 1907 can be associated with the so-called Panic of 1907. Likewise, in the early 1930s, real prices plummeted as the (second) Great Depression reduced global demand for commodities.

After World War II, positive aggregate commodity demand shocks led to increases in real commodity prices as re-industrialization and re-urbanization in much of Europe and Japan proceeded, followed by the economic transformation of the East Asian Tigers (following Japan's lead.)

Negative aggregate commodity demand shocks are evident in the late 1970s, the early 1980s and the late 1990s, respectively corresponding to the global recessions of 1974 and 1981 and the Asian financial crisis of 1997. These are followed by a series of positive aggregate commodity demand shocks emerging from the late 1990s and early 2000s due to unexpectedly strong global growth, driven by the industrialization and urbanization of China.

Finally, the lingering effects of the global financial crisis are also clearly visible.

Demand Dominates Supply

From 1871 to 2013, aggregate commodity demand shocks explained 32-38 percent of the variation in real commodity prices (across the three types of commodities examined here), while commodity market-specific demand shocks explained 42-50 percent (Table 1A). These two types of shocks, thus, caused an appreciable portion – 74-88 percent – of medium- and long-run fluctuations in real commodity prices.

Table 1
Different Types of Shocks Explain Commodity Price Booms, Busts

Percentage share of each type of shock that explains commodity price fluctuations

Panel A: 1871-2013

	Aggregate commodity demand shock	Commodity supply shock	Commodity-specific demand shock
Grains	32%	18%	50%
Metals	38%	20%	42%
Softs	34%	20%	44%
Total	35%	20%	46%

Panel B: 1871-1913

	Aggregate commodity demand shock	Commodity supply shock	Commodity-specific demand shock
Grains	26%	23%	52%
Metals	33%	24%	44%
Softs	27%	24%	48%
Total	29%	24%	47%

Panel C: 1919-1939

	Aggregate commodity demand shock	Commodity supply shock	Commodity-specific demand shock
Grains	32%	19%	49%
Metals	34%	27%	38%
Softs	35%	19%	46%
Total	34%	23%	45%

Panel D: 1949-2013

	Aggregate commodity demand shock	Commodity supply shock	Commodity-specific demand shock
Grains	37%	16%	47%
Metals	42%	16%	42%
Softs	38%	18%	45%
Total	38%	16%	46%

Source: Jacks and Stuermer (2018).

Conversely, commodity supply shocks played a rather secondary and transient role, explaining only 18-20 percent of the variation. This result is fairly consistent across agricultural, mineral and soft commodities.

Averages for three subperiods based on the full sample (Table 1B-D) show that commodity supply shocks have lost importance over time, as their average share declined from 24 percent in the period before World War I to 23 percent during the interwar period and fell further to 16 percent in the period after World War II.

At the same time, the average share of aggregate commodity demand shocks has increased from 29 percent in the pre-World War I period to 34 percent during the interwar period and up to 38 percent in the post-World War II period.

On average, the effects of aggregate commodity demand shocks are the most persistent, with effects lingering up to 10 years. Commodity market-specific demand shocks are slightly less persistent but with effects also lasting up to 10 years in some cases. Finally, effects of commodity supply shocks, for the most part, are insignificant. The sugar and tin markets are exceptions to this generality, with significant effects lasting up to five years.

Persistent, Low Prices

After examining the drivers of real commodity prices in the long run among different types of commodities, aggregate commodity demand shocks and commodity market-specific demand shocks appear to strongly dominate over commodity supply shocks in driving fluctuations of real commodity prices over a long period of time.

The results suggest that the price effects of the large commodity demand shocks attributable to China in 2003-07 and 2009-11 will dissipate. In the absence of additional positive commodity demand shocks, it appears that current prices may stay low while abundant supplies are consumed. Commodity exporters should, thus, prepare for a prolonged period of depressed commodity prices.

Endnotes

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Dr. Stuermer presented on this article's topic at the JPMCC's August 2017 international commodity symposium, which took the place of the JPMCC's annual Research Council meeting. The views expressed here are those of the author and do not represent the views of the Federal Reserve Bank of Dallas or the Federal Reserve System.

1 See Stuermer (2017) for an empirical exploration of the relationship between industrialization and mineral commodities.

2 For details on the data, methodology and results, see Stuermer (2018) and Jacks and Stuermer (2018).

3 For each commodity market, a Structural Vector Autoregressive Model with long-run restrictions is used. It includes three endogenous variables—global gross domestic product (%), global commodity production (%) and world commodity price (ln). The model also controls for constant, linear trends and the world war periods.

4 See Kilian (2009).

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Harvesting Commodity Styles: A Flexible Integration Framework

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Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3005347

The authors develop a flexible investment framework that nests standalone styles and integrations thereof and can be applied in a long-short, long- or short-only fashion to any asset class in zero net supply. Motivated by the unsettled debate on how to best model commodity risk premia, the usefulness of integration is demonstrated in the context of a "universe" of eleven long-short commodity styles. The results confirm the superiority of the equal-weights integration (EWI) portfolios vis-à-vis each of the standalone-style portfolios in terms of the reward-to-risk and crash risk profiles. The naïve EWI is not challenged by sophisticated integrations with time-varying, heterogeneous style weights based on past returns according to utility maximization, principal components or style-rotation among other criteria. The findings hold after trading costs, variants of the sophisticated integrations, sub-period analysis and data snooping tests.

Introduction

The literature on commodity futures pricing has established that investment strategies that acknowledge the phases of backwardation and contango are able to capture sizeable risk premium. Accordingly, since the backwardation (contango) phase signals a subsequent rise (fall) in futures prices, three commodity futures investment styles have been proposed that buy at each portfolio formation time, respectively, the commodities with the most downward sloping forward curves (Erb and Harvey, 2006), the best past performance (Miffre and Rallis, 2007), the highest net-short hedging and net-long speculators ratios (Dewally *et al*., 2013), and sell the commodities with opposite values for those signals. Aside from these "traditional" styles, the literature also suggests styles based on liquidity, change in open interest, inflation beta, dollar beta, value, volatility or skewness signals (Hong and Yogo, 2012; Asness *et al*., 2013; Szymanowska *et al*., 2014; Fernandez-Perez *et al*., 2018).

This paper is concerned with *style integration*. The authors develop a flexible investment framework that nests standalone styles and integrations thereof. Among the style-integration methods considered, some of them have already been studied in the literature (which has focused mainly on equity markets) whereas others are novel integrations. First, the proposed integration framework is general enough to accommodate long-short, long- and short-only portfolios for any asset class in zero net supply. Second, given the host of long-short commodity futures styles available to capture risk premia and the dearth of research on commodity style integration, the paper fills a gap by providing a comprehensive analysis to

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assess from the dual perspective of reward-risk trade-off and crash risk, including i) the benefits of commodity style integration versus standalone style investing, and ii) the effectiveness of various integration methods.

Why the Paper's Research Question is Important

Research over the last few years has found that a number of factors can explain return performance in commodity futures, but an exhaustive analysis of how to gain exposure to all these factors in a portfolio has not been provided. Improving the return profile through mixing styles is, in fact, the critical issue for many commodity investors. This paper fills this gap by developing an integration framework that can assist practitioners towards easily constructing long-short, long- or short-only commodity portfolios with simultaneous exposure to several commodity styles. The investment framework is flexible enough to facilitate style integration of any asset class in zero net supply. The integration of 11 styles in this paper for a cross-section of 28 commodity futures contracts using a host of integration approaches is an important investment management exercise for anyone who wants to blend commodity risk factors within a portfolio. The integration framework is also relevant for academics because it facilitates a structured approach towards developing new integration approaches and towards a more theoretical investigation of their relative strengths and weaknesses.

Methodology: A Flexible Framework for Asset Allocation

The decisions at portfolio formation time *t* about the relative wealth to allocate to each asset and the nature of the position, long versus short, are represented by the $N \times 1$ *asset-weighting* (or asset allocation) vector $\boldsymbol{\phi_t}$ defined as

$$\boldsymbol{\phi_t} \equiv \boldsymbol{\Theta_t} \times \boldsymbol{\omega_t} = \begin{pmatrix} \theta_{1,1,t} & \cdots & \theta_{1,K,t} \\ \vdots & \ddots & \vdots \\ \theta_{N,1,t} & \cdots & \theta_{N,K,t} \end{pmatrix} \begin{pmatrix} \omega_{1,t} \\ \vdots \\ \omega_{K,t} \end{pmatrix} = \begin{pmatrix} \phi_{1,t} \\ \vdots \\ \phi_{N,t} \end{pmatrix} \tag{1}$$

where $\boldsymbol{\Theta_t}$ is the $N \times K$ *score* matrix (*N* is the number of assets and *K* the number of styles) and $\boldsymbol{\omega_t}$ is the $K \times 1$ *signal- (or style) weighting* vector. The sign of the *i*th asset allocation weight $\phi_{i,t}$ dictates the type of position (long or short); long positions are characterized by $\phi_{i,t}^L \equiv \phi_{i,t} > 0$, and short positions as $\phi_{i,t}^S \equiv \phi_{i,t} < 0$. Given the focus of the paper on long-short styles, the entry $\theta_{i,k,t}$ of the matrix $\boldsymbol{\Theta_t}$ is a ternary score assigned to asset *i* according to the *k*th signal, i.e. scores $\theta_{i,k,t} \in \{-1,0,1\}$ which means that 1 is assigned to the quintile of assets (20%*N*) whose prices are expected to increase the most (or to decrease the least), -1 is assigned to the 20%*N* assets whose prices are expected to increase the least (decrease the most) and 0 to all other assets.

The weight $\omega_{k,t}$ reflects the relative importance given to the *k*th individual investment style (or factor) in the integrated portfolio. In the trading exercise, we assume that the investor's mandate is fully invested at each portfolio formation time *t*. For this purpose, the asset allocation weights are normalized so that, in absolute value, they sum to 1; namely, $\sum_{i=1}^{N} |\tilde{\phi}_{i,t}| = 1$ with $\tilde{\phi}_{i,t} = \phi_{i,t} / \sum_{i=1}^{N} |\phi_{i,t}|$. The fully-collateralized long-short integrated portfolio thus constructed at month-end *t* according to the asset allocation weights $\tilde{\phi}_{i,t}, i = 1, \dots, N$ is held for one month to provide the excess return $r_{LS,t+1} = \sum_{i=1}^{N} \tilde{\phi}_{i,t} r_{i,t+1} = \sum_i \tilde{\phi}_{i,t}^{L} r_{i,t+1} - \sum_j |\tilde{\phi}_{j,t}^{S}| r_{j,t+1}$ where $r_{i,t+1} \equiv ln \frac{P_{i,t+1}}{P_{i,t}}$ is the *i*th asset return. With the ternary scoring scheme $\theta_{i,k,t} = \{-1,0,1\}$ the above normalization implies that $\sum_i \tilde{\phi}_{i,t}^{L} = 0.5$ and $\sum_j \tilde{\phi}_{j,t}^{S} = -0.5$; that is, 50% of the investor's mandate is allocated into long positions and the remaining 50% of her mandate into short positions.

Results

The authors illustrate the integration framework for K=11 commodity styles that exploit as trading signals, respectively, the roll-yield, hedgers' net short positions, speculators' net long positions, momentum, value, volatility, open interest, liquidity, US$ betas, inflation betas and skewness. The standalone and integrated long-short portfolios are constructed using 28 commodity futures contracts from January 1992 to April 2016.

The naïve EWI strategy (with time-constant, homogeneous exposure to the *K* styles, *i.e.*, $\boldsymbol{\omega_t} = \left(\frac{1}{K}, \dots, \frac{1}{K}\right)'$) outperforms each of the individual styles in terms of risk-reward profile and crash risk measures (e.g., downside volatilities, 99% Value-at-Risks and maximum drawdowns). This finding confirms the diversification benefits of style integration. Another key result is that the risk-reward and crash risk profiles of the unsophisticated integrated portfolios (i.e., those formed according to the naïve EWI approach) are not challenged by those of any of the sophisticated integrated portfolios (i.e., those formed according to time-varying, heterogeneous sample-based weights).

Why Does the Unsophisticated Equal-Weighted-Integration Excel?

In essence, a key finding of the paper is that "less is more" in terms of the sophistication of the integration method. A rationale for this result is that albeit the sophisticated integration approaches can discriminate better among the *K* styles (given that they allow time-varying, heterogeneous exposures to the different styles), this potential advantage is contaminated by two sources of *uncertainty*. On the one hand, a finite sample of *past* returns (for each of the individual styles) is used by the sophisticated integrations to obtain the style weights at each portfolio formation time – this implies estimation error. On the other hand, past performance is not a guarantee for future performance; namely, the fact that the *k*th style outperformed the *j*th style in the past window preceding time *t* according to some criteria (which will be reflected as $\omega_{k,t} > \omega_{j,t}$ in the sophisticated integration) does not imply that it will do so subsequently.

In particular, the naïve EWI approach is appealing because: i) it does not suffer from estimation error, ii) it reduces the scope for data mining because by fixing the style exposures (or signal weights) at $\frac{1}{K}$ the investor does not need to carry out a "pre-ranking" of the *K* individual styles which, depending on the underlying integration criteria, may hinge on *ad-hoc* choices to determine the weights (e.g., length of past window, investor's utility assumptions, and so forth), and iii) it is easy to implement.

Conclusions

A large number of factor models have been suggested to explain returns in commodity markets, but to date there have been no attempts at integrating all of them in a single portfolio structure. The simple motivation for style integration is to more reliably identify the commodities with the most (least) attractive expected returns. This paper undertakes this task by integrating a “universe” of 11 commodity styles; some of these are classics across all asset classes like carry, value and momentum, but a number of them are more specific to commodities. A key issue that this paper investigates, which is true for any asset class, is how to blend the factors. The authors offer a structured approach to commodity investors that seek exposure to multiple styles, formalizing a flexible framework that accommodates a host of integration methods and nests all the standalone styles as particular cases. The framework is flexible enough to be applicable in a long-short, long- or short-only fashion for any asset class in zero net supply. Their conclusion is simple and straight-forward – by equally weighting all styles constantly over time, you will get a more attractive return-to-risk portfolio than by focusing on one style only or integrating more styles in a more sophisticated fashion.

Endnotes

The paper that this digest article summarizes was the winner of the Commodity and Energy Markets Association (CEMA) Best Paper Award at CEMA’s Oxford University conference in 2017.

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Keywords

Style integration, commodity markets, long-short investment, asset allocation, portfolio choice.

Commodities Momentum: A Behavioral Perspective

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The authors study the 52-week-high momentum trading strategy in commodity futures markets. Their empirical analysis suggests that this behavioral-finance motivated strategy generates significant profits after accounting for transaction costs, and outperforms the conventional momentum strategy. They further demonstrate that the 52-week-high momentum returns are significantly linked not only to the term structure and hedging pressure risk factors that reflect the inexorable contango and backwardation cycle but also to the TED spread that proxies for global liquidity risk.

Introduction

In a rational, efficient capital-markets setting, asset prices are expected to adjust to new information instantaneously. However, behavioral theorists have long argued that investors are not always rational, and there are sometimes delayed asset price reactions which reflect that investors respond gradually to new information. In particular, early evidence suggests that futures prices do not follow random walks and do not react to news in a fully rational manner (Stevenson and Bear, 1970; Cargill and Rausser, 1975; Leuthold, 1972); therefore, trading strategies can be used profitably to exploit predictable patterns in prices. Against this background, the authors analyze the "52-week-high momentum" strategy to shed light on the behavioral phenomenon known as *conservatism bias* in the context of commodity futures investors.

Relevance of the Research Question

The commodity futures pricing literature has made considerable progress in the last decade. In particular, a three-factor model that consists of term structure/carry, hedging pressure and momentum factors continues to gain acceptance in the commodities pricing literature (Basu and Miffre, 2013; Szymanowska *et al.,* 2014; Bakshi *et al.,* 2017). However, the literature has still not reached a consensus on what constitutes an appropriate commodity futures pricing model. As regards the rationale for commodities momentum, the evidence suggests that the term structure and hedging pressure factors provide only a partial explanation of the abnormal returns. After controlling for these risk factors, the driving forces of conventional momentum in commodities can be seen as largely behavioral. However, previous studies have shown that market sentiment proxies such as the CBOE implied volatility index,

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VIX (or investor fear gauge), and the CBOE Crude Oil ETF volatility index (or OVX) are not able to explain the variation of conventional momentum returns. This paper contributes to the momentum literature by showing that a behavioral 52-week high/low proxy is largely able to explain conventional commodity momentum returns.

Data and 52-Week High and Low Nearness Signal

The sample consists of settlement prices for 30 commodity futures contracts from 6 sectors (energy, precious metals, industrial metals, livestock, grains and softs) from January 1977 through July 2013. At each month end, the commodities are sorted into winner (long) and loser (short) portfolios based on the 52-week high ratio which is defined as $P_{i,t-1}/high_{i,t-1}$, where $P_{i,t-1}$ is the price of commodity i at the end of month $t-1$ and $high_{i,t-1}$ is its highest price during the preceding 52-week period. The 52-week low momentum strategy is constructed in a similar way but the ranking signal is instead the 52-week low ratio defined as $P_{i,t-1}/low_{i,t-1}$, where $P_{i,t-1}$ is the price of commodity i at the end of month $t-1$ and $low_{i,t-1}$ is its lowest price during the prior 52-week window. All portfolios are rebalanced monthly with no monthly gap skipped between ranking and holding periods. The long-short portfolio constituents are equally-weighted.

Performance of 52-Week High and Low Momentum Portfolios

The paper begins by showing that the "52-week-high momentum" and the "52-week-low momentum" strategies are profitable (generating a mean excess return above 14% per annum) in commodity futures. Consistent with prior studies about the influence of investor irrationality in equity markets, these findings confirm the conservatism hypothesis and also indicate the presence of a strong anchoring behavior (i.e., investors rely too heavily on one piece of information when making decisions) in commodity futures markets. This suggests that investors use the 52-week high and low prices as reference points (or "anchors") in processing news on commodities. When good news pushes the commodity futures price near or above their 52-week high, traders are reluctant immediately to bid the price higher even if the information warrants it. Similarly, when bad news pushes prices far below their 52-week high, investors are initially unwilling to sell. When traders eventually act on the information, prices adjust to a new equilibrium thus resulting in return continuation.

Further the paper shows that the 52-week-high momentum strategy performs better than the conventional momentum strategy proposed by Miffre and Rallis (2007). Furthermore, the 52-week-high momentum strategy is able to explain a large portion of the returns variation in conventional momentum portfolios. This suggests that commodity futures momentum is attributable to the anchoring behavior of investors.

They also find that returns to the 52-week-high momentum strategy become negative from month 12 onwards and fully reverse (back to zero) around month 30. While the equity markets literature has not found evidence of long-term reversals in the 52-week-high momentum returns, the findings in this paper suggest that short-term momentum and long-term reversal co-exist in commodity futures markets.

The authors find that the winner-loser returns of the 52-week-high momentum strategy are significantly explained by the Treasury Bill versus Eurodollar (TED) spread, an indicator of perceived credit risk in the general economy; namely, the returns reflect compensation for global funding liquidity risk exposure. Furthermore, the 52-week-high momentum strategy is negatively related to the bottom quintile of investor sentiment changes; thus, the strategy works better in more stable market conditions, that is, when the shifts in market sentiment are smaller.

Finally, a sub-period analysis confirms a significant decline in the commodity momentum profitability in the last decade. This pattern is consistent with predictions stemming from the adaptive market hypothesis (AMH) which states that the behavioral biases of market agents, such as anchoring, heuristics, and underreaction, continue to exist because agents adjust their behavior to survive in a rapidly evolving market environment. The anchoring behavior of commodity futures traders may have changed due to the relentless growth of commodity markets since the early 1990s and the introduction of the Commodity Futures Modernization Act of 2000; namely, the increased competition of hedge funds, commodity trading advisors, managed futures and commodity index products may have gradually eroded momentum profitability.

Conclusions

Momentum strategies have been examined extensively in the commodities literature. While a number of studies argue that momentum is a proxy for the backwardation/contango cycle, this paper demonstrates that the anchoring behavior of investors plays also a role. The empirical analysis in the paper reveals also a structural decline in recent years in the profitability of conventional and the proposed 52-week high/low momentum strategies. Since the efficient markets hypothesis and behavioral theories are unable to rationalize such a decline, the authors ascribe a role to the evolution-based adaptive market hypothesis, as it provides a better approximation of the changing nature of commodity futures markets as regards its participants.

Endnotes

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Keywords

Momentum, term structure, hedging pressure, conservatism, adaptive markets, liquidity.

Pairs Trading, Technical Analysis and Data Snooping: Mean Reversion vs. Momentum

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This article examines the performance of technical rules applied to the commodity arbitrage (pairs-trading) investment strategy using daily data from 1990 to 2016. Adopting the false discovery rate method to control for data snooping bias and exercising 18,412 technical trading rules, significant predictability and excess profitability are observed. An out-of-sample analysis is performed to cross-validate the results in different sub-periods. The main finding is that whilst the performance of pairs-trading based on technical analysis exhibits a downward trend over the sample period, the opportunity for significant pairs-trading excess profitability remains.

Introduction

Pairs trading is a relative-value arbitrage strategy that matches a long position with a short position in a pair of highly correlated instruments. This 35-year-old trading approach remains popular among hedge funds as well as investment managers.

This paper investigates the excess profitability of pairs trading on daily data including spreads on *commodities* from January 1990 to December 2016, while considering a "universe" of *technical trading rules* (TTRs). The excess returns from technical analysis have shrunk over time, but transaction costs do not fully neutralize them: break-even transaction costs exceed conservative historical estimates of actual transaction costs. The authors also examine the time-varying excess returns of technical analysis on pairs trading in an out-of-sample (OOS) framework. Generally, the results suggest a decay in profitability in recent years; however, portfolios of significant pairs-trading rules on commodity pairs can still achieve attractive Sharpe ratios. Overall the findings are consistent with those of Gatev *et al*. (2006) in suggesting that simple mean reversion is *not* the only factor behind the significant profits but also momentum.

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Relevance of the Research Question

Technical analysis is widely employed by innovative classes of investors, such as hedge fund managers, as a strategy that is deemed to capture higher performance, lower risk and superior market-timing ability than other strategies (Smith *et al*., 2016). It is important to conduct a comprehensive and robust investigation of its merits since it is quite easy to confuse "luck" with true "skill"; namely, classical statistical inference focusing on single hypothesis testing of each (of multiple) trading rules can easily lead to false rejections or the so-called *p*-hacking phenomenon (see Harvey, 2017). The present study seeks to fill this gap in the context of commodity-pairs technical trading.

Technical Trading Rules Universe and Data-Snooping-Bias Control

Seven main families of TTRs based on past price data of the computed pairs are considered. Those classes of rules are categorized as *momentum* and *mean-reverting* rules. The momentum rules include: *filter rules*, *moving averages*, *support and resistance rules* and *channel breakouts*. The mean-reverting rules include: *relative strength indicators, Bollinger bands*, and c*ommodity channel index rules*. For each family, numerous parameterizations are employed (e.g., delay-period filters, holding-period filters, and fixed local maximum/minimum values), summing up to about 18,000 rules.

An appropriate investigation of significant profitability of a "universe" of TTRs requires controlling for data snooping bias. This paper adopts the *false discovery rate* (FDR) test of Barras *et al*. (2010) which estimates the proportion of false discoveries among strategies performing better or worse than the benchmark (e.g., risk-free rate), while displaying genuine performance under a specific threshold. The method assesses multiple strategies concurrently in a cross-section structure using the Sharpe ratio. The popularity of the FDR lies in the fact that by tolerating a certain, usually small, amount of Type I error, the FDR has more power to detect significantly profitable strategies.

The full-sample historical sample performance of TTRs on commodities pairs indicates that all commodity pairs are significantly predictable at the 1% or 5% nominal level, namely the Brent-WTI, platinum-gold, platinum-palladium, and corn-ethanol pairs. The Brent-WTI pair (or spread) seems to be the most predictable pair with 563 TTRs producing positive performance, while in terms of economic magnitude, the best-performing rule yields an outstanding mean excess return of 17.6% per annum and a healthy Sharpe ratio of 1.20. For the rest of commodities, the number of significantly predictive rules, range from 6 to 12, while the best-performing rules generate very promising annualized mean excess returns varying from 2.03% to 8.57%, with Sharpe ratios from 0.45 to 0.61.

To conduct the OOS analysis of pairs-trading performance the authors divide the full sample period into five sub-periods and adopt a 70-30 split for the in-sample versus OOS years in each of them. Then they construct FDR equally-weighted portfolios of each pair's significant rules based on in-sample performance and evaluate them in the OOS periods. The Brent-WTI crude oil pair seems again the most promising, yielding positive Sharpe ratios above 1 for the first two OOS periods (i.e., 1997 and 2001). For the platinum-gold pair, the TTRs reach their highest Sharpe ratio of 1.83 during 2011 which then fall back to 0.60 on average during 2016. For the platinum-palladium and corn-ethanol pairs, the significant TTRs yield positive performance for the majority of OOS subperiods, but the Sharpe ratios are smaller in magnitude, generally below 1. The findings confirm the diversification benefits of the FDR method in enabling a portfolio of pairs-trading rules with significant profitability and relatively small downside risk.

Following what is common practice among *contrarian* pair-traders, the authors examine the OOS performance of specific contrarian TTRs, setting the lookback period equal to the half-life of an optimal mean-reverting strategy. In this context, the most promising results are obtained by trading the Brent-WTI crude oil spread, albeit its returns also decay to zero after reaching the third post-sample year.

Another popular pairs trading technique the authors considered is based on information from the *cointegrating* relation (i.e., long run co-movement) of the two assets to dynamically create hedge ratios. Here the Brent-WTI pair shows a consistently positive performance for all OOS years except one (2011) reaching its highest level in the last year (2016) with a very attractive Sharpe ratio of 2.02.

The final OOS simulation conducted in the paper is for an integrated market portfolio for all commodity pairs based on the TTRs selected, which are in-sample significant in terms of Sharpe ratio according to the FDR method for every pair. Its performance is compared with identical integrated portfolios constructed under the half-time, mean-reverting significant rules as well as with similar ones based on the significant rules identified using the dynamic hedging technique. The integrated commodities portfolio achieves a very healthy performance across all OOS years, yielding mostly Sharpe ratios of up to 1.73 and an average *compounded annual growth rate* (CAGR) of 2.24%. The analogous commodities portfolio constructed under the half-time of mean-reversion criterion yields attractive performance at least during the first two OOS years; in 1996 and 2001 the corresponding Sharpe ratios (0.86 and 1.05) and CAGRs (4.32% and 7.80%) indicate some good arbitrage opportunities, which subsequently decay. Finally, the commodities' portfolio performance based on pairs constructed under the dynamic hedging reveals similar evidence with the ones employing no hedging. The commodities' portfolio again outperforms during the first two post-sample periods with Sharpe ratios ranging from 1.01 to 1.82 and CAGRs from 2.42% to 5.58%, which then decay 0.20% and 0.11% over the recent period.

Conclusions

A hedge fund trading strategy based on the assumption of price *cointegration* in an efficient market is investigated in order to anticipate potentially profitable commodity-pair spreads. For this purpose, a large universe of technical trading rules is examined over a long sample period while adopting a robust multiple hypothesis testing method that attempts to shield the findings from data mining biases. The empirical evidence provided in this paper suggests that technical trading still has predictive power for most of the spreads considered, as it is able to yield attractive Sharpe ratios that remain significant after conservative transaction costs. An out-of-sample trading simulation exercise reveals that although the excess profitability of technical pairs-trading has gradually shrunk in recent years, some commodity pairs still exhibit attractive performance.

Endnotes

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Keywords

Pairs trading, technical analysis, data snooping, market efficiency.

The Amaranth Case Study

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The Winter 2017 issue of the *Global Commodities Applied Research Digest* (*GCARD*) provided a case study on the MF Global bankruptcy. In this issue of the *GCARD*, we will cover another debacle: the Amaranth hedge fund debacle. While the lessons from the MF Global bankruptcy can best be understood in terms of due diligence principles, the Amaranth blowup can best be understood in terms of market-risk principles, as will be discussed in this article.

Amaranth Advisors, LLC was a multi-strategy hedge fund, founded in 2000 and headquartered in Greenwich, Connecticut. The founder's original expertise was in convertible bonds. The fund later became involved in merger arbitrage, long-short equity, leveraged loans, blank-check companies, and in energy trading. As of June 30, 2006, energy trades accounted for about half of the fund's capital and generated about 75 percent of its profits.

Davis (2006) provides an excellent overview on Amaranth's energy trading. Davis (2006) reports that Amaranth's head energy trader sometimes held "open positions to buy or sell tens of billions of dollars of commodities." Amaranth's energy trading operation was based in Calgary, Alberta. "[Amaranth's head energy trader] saw that a surplus of [natural] gas … [in the] summer [in the United States] could lead to low prices, but he also made bets that would pay off if, say, a hurricane or cold winter sharply reduced supplies by the end of winter." Excerpting from key points in Davis (2006)'s article:

- Amaranth's hedge energy trader "also was willing to buy gas in even further-away years, as part of complex strategies."

- "Buying what is known as 'winter' gas years into the future is a risky proposition because that market has many fewer traders than do contracts for months close at hand."

- "Unlike oil, [natural] gas can't readily be moved about the globe to fill local shortages or relieve local supplies."

- "[Natural gas] traders … make complex wagers on gas at multiple points in the future, betting, say, that it will be cheap in the summer if there is a lot of supply, but expensive by a certain point in the winter. [Amaranth's head trader would] closely watch how weather affects prices and whether conditions will lead to more, or less, gas in a finite number of underground storage caverns."

Amaranth's structural position-taking may have assisted energy companies in their need to hedge their far-forward production, including through 2010. Davis (2006) writes: "[Amaranth's energy book] was up for the year roughly $2 billion by April [2006], scoring a return of 11% to 13% that month alone, say investors in the Amaranth fund. Then … [the energy strategies] … had a loss of nearly $1 billion in May [2006] when prices of gas for delivery far in the future suddenly collapsed, investors add. [The energy traders] won back the $1 billion over the summer …"

As of August 31, 2006, the fund had about $9.2 billion in assets under management. On Monday, September 18, 2006, market participants became aware of Amaranth's distress. The founder had issued a letter to investors informing them that the fund had lost an estimated 50 percent of their assets since its end-August value. Additionally, Hamilton (2006) notes the fund had lost $560 million on Thursday, September 14, 2006 alone.

According to Davis, Zuckerman, and Sender (2007), the fund had scrambled to transfer its positions to third-party financial institutions during the weekend of September 16 and 17, 2006. Merrill Lynch had agreed to take on 25 percent of the fund's natural gas positions for a payment of about $250 million. The fund then lost $800 million more through Tuesday, September 19, 2006, due to the natural gas market moving severely against its positions. On Wednesday, September 20, 2006, the fund succeeded in transferring its remaining energy positions to Citadel Investment Group and to its clearing broker, J.P. Morgan Chase, at a $2.15 billion discount to their September 19, 2006 mark-to-market value. Apparently, the two firms equally shared the risk of Amaranth's positions. On Thursday, September 21, 2006, the natural gas curve stabilized. The hedge fund's losses ultimately totaled $6.6 billion.

On June 25, 2007, the U.S. Senate Permanent Subcommittee on Investigations released a report on the Amaranth debacle, entitled, "Excessive Speculation in the Natural Gas Market." The 135-page report and its further 345 pages of appendices provided details on the Amaranth case. In carrying out its forensic analysis, the Senate subcommittee examined several million individual trades. The subcommittee obtained this information by subpoenaing records from the New York Mercantile Exchange (NYMEX), the Intercontinental Exchange (ICE), Amaranth, and other traders.

Amaranth's spread trading strategy involved taking long positions in winter contract deliveries and short positions in non-winter contract deliveries. These positions would have benefited from potential weather events such as hurricanes and cold-shocks from 2006 through 2010. Although one can justify the economic rationale for Amaranth's strategy, both trade sizing and value matter even more so. The U.S. Senate Permanent Subcommittee on Investigations Staff Report (2007) found that in late July 2006, Amaranth's natural gas positions for delivery in January 2007 represented "a volume of natural gas that equaled the entire amount of natural gas eventually used in that month by U.S. residential consumers nationwide."

Drawing from the U.S. Senate's report, Table 1 summarizes the scale of Amaranth's natural gas trading activity. Figure 1 on the next page draws from the report's appendix to show the positioning of the fund through May 2009, as of the end of August 2006. The U.S. Senate report excludes similar charts for the fund's positions past the May 2009 maturity date and also its miscellaneous commodity investments.

Table 1

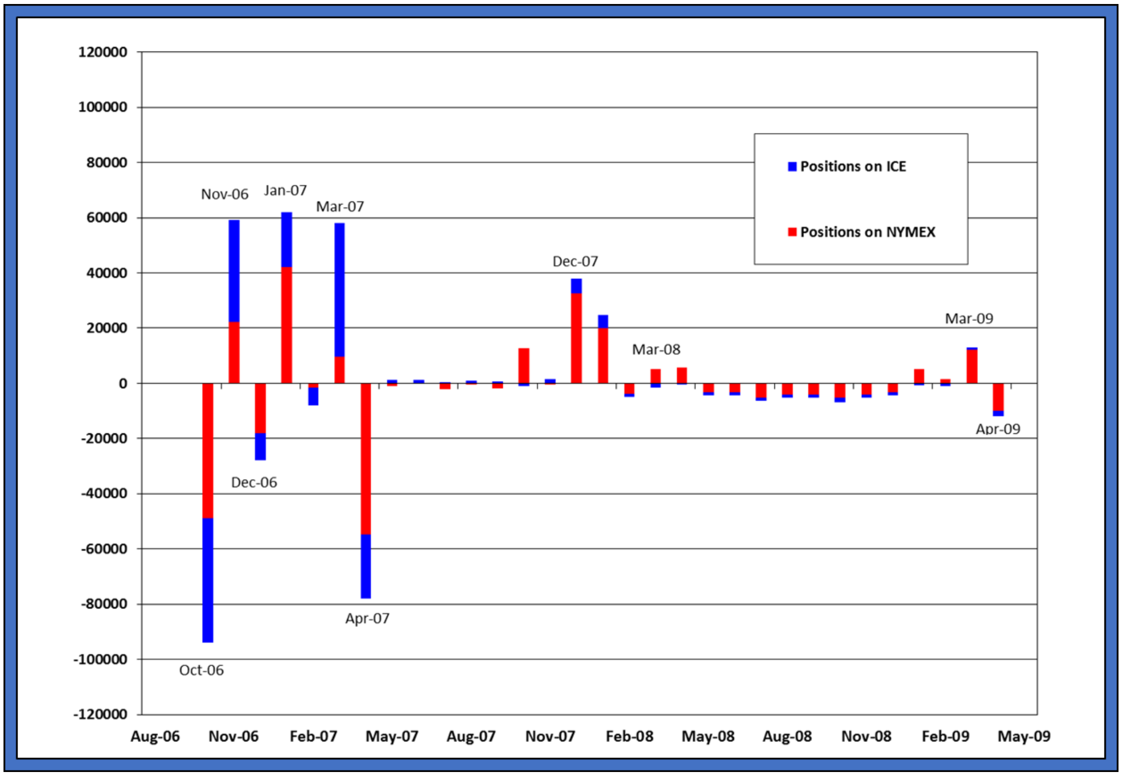
Scale of Amaranth's Natural Gas Trading: Excerpted from the U.S. Senate Report of June 25, 2007

At times Amaranth controlled up to 40% of all the open interest on NYMEX for the winter months (October 2006 through March 2007).	pp. 51-52
In late July 2006, Amaranth held a total of more than 80,000 NYMEX and ICE contracts for January 2007, representing a volume of natural gas that equaled the entire amount of natural gas eventually used in that month by U.S. residential consumers nationwide.	p. 52
On 7/31/06, Amaranth's trading in the March and April 2007 contracts represented almost 70% of the total NYMEX trading volume in each of these contracts on that date.	p. 52
Amaranth also held large positions in other winter and summer months spanning the five-year period from 2006-2010.	p. 52
For example, Amaranth held 60% of the outstanding contracts (open interest) in all NYMEX natural gas futures contracts in 2010.	p. 52
On 7/24/06, Amaranth's futures position as a % of NYMEX futures open interest in the December 2007 contract was 81%.	p. 94
On 8/28/06, Amaranth accounted for over 40% of the total volume on the ICE, and over 25% of the entire volume of exchange-traded futures and swaps on NYMEX and on ICE on that date.	p. 101

Source: Excerpted from U.S. Senate Permanent Subcommittee on Investigations Staff Report (2007). The right-hand column shows on what page of the Staff Report that each point is derived from.

NYMEX: New York Mercantile Exchange; ICE: Intercontinental Exchange

Figure 1
Amaranth's Positioning on August 31, 2006 in Natural Gas Contracts on NYMEX and ICE



Source: Adapted from U.S. Senate Permanent Subcommittee on Investigations Staff Report (2007), Appendix V, p. 38.

Amaranth's position sizes were obviously too large for a financial entity that had no physical energy assets. If a financial firm cannot make or take physical delivery of a commodity, then that firm's exit strategy is very constrained. Also, the fund had entered into these vast positions at exceedingly wide levels for these spreads.

Using the Senate report's documented positions for Amaranth as of August 31, 2006, Till (2008) finds that two spreads were 93 percent correlated to Amaranth's natural gas book: (1) the November 2006 vs. October 2006 (NGX-V6) spread and (2) the March 2007 vs. April 2007 (NGH-J7) spread.

Examining the past spread values for the November-versus-October-2006 spread and the March-versus-April-2007 spread helps to understand the riskiness of Amaranth's documented August 31, 2006 portfolio. If these two spreads had reverted to levels that had prevailed at the end-of-August during the previous six years, up to –36 percent could have been lost under normal conditions, as shown in Table 2 on the next page.

Table 2
Scenario Analysis of Amaranth's Key Risk Positions (August 31, 2006)

Number of Contracts	Spread Symbol	Natural Gas Spread	8/31/06 Level
(105,620)	NGV-X	October-November	-2.18
59,543	NGH-J	March-April	2.14

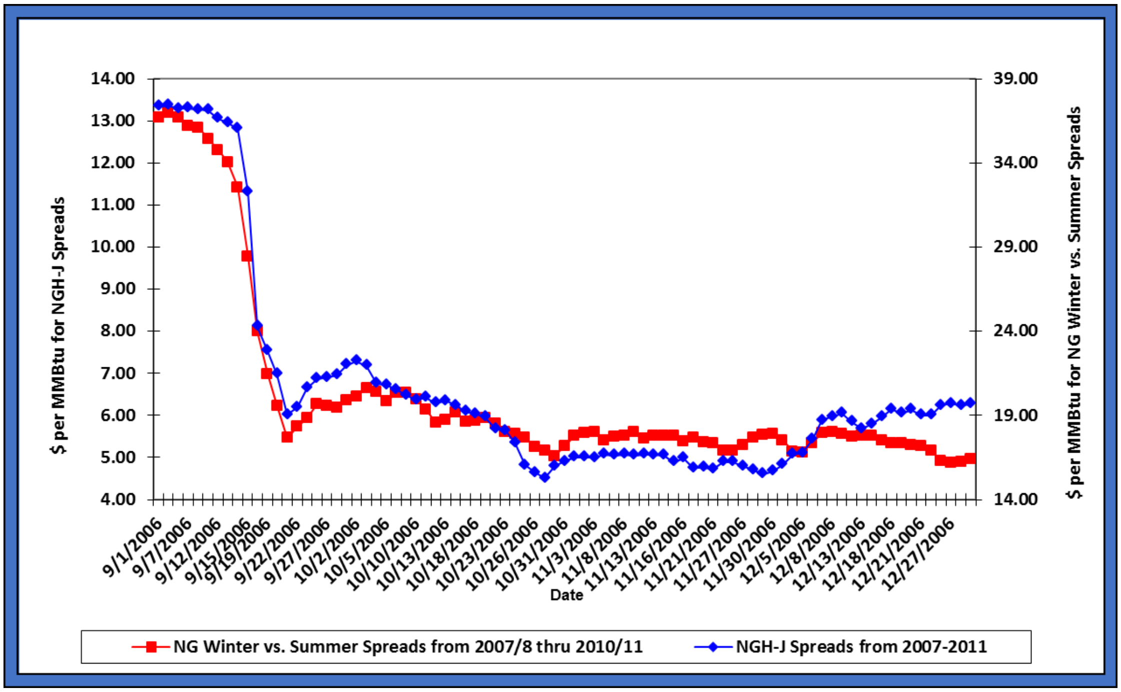
Date	NGV-X	NGH-J	Losses due to V-X	Losses due to H-J	Total Losses	Portfolio Loss
8/31/2000	-0.058	0.26	$ (2,241,256,400)	$ (1,119,408,400)	$ (3,360,664,800)	*-36.5%*
8/31/2001	-0.33	0.09	$ (1,953,970,000)	$ (1,220,631,500)	$ (3,174,601,500)	*-34.5%*
8/31/2002	-0.33	0.113	$ (1,953,970,000)	$ (1,206,936,610)	$ (3,160,906,610)	*-34.4%*
8/31/2003	-0.25	0.44	$ (2,038,466,000)	$ (1,012,231,000)	$ (3,050,697,000)	*-33.2%*
8/30/2004	-0.643	0.57	$ (1,623,379,400)	$ (934,825,100)	$ (2,558,204,500)	*-27.8%*
8/31/2005	-0.185	2.24	$ (2,107,119,000)	$ 59,543,000	$ (2,047,576,000)	*-22.3%*

Source: Premia Research LLC.

This analysis is based on Amaranth's portfolio as of August 31, 2006, which was two weeks before the fund's implosion. One caveat with this analysis is that it is based solely on the positions documented in the U.S. Senate report's graphical appendix. In mid-September 2006, the fund had lost more than $2 billion month-to-date. At this point the critical-liquidation-cycle was initiated for the fund, a vicious circle in which distressed liquidations cause even greater losses, leading to even greater calls for margin from a fund's credit-providers, which then leads to even more distressed trading. In the case of Amaranth, no natural (financial) counterparty existed who could entirely take on the fund's positions during a very short period when the fund became distressed in mid-September 2006. The natural counterparties to Amaranth's trades were the physical-market participants who had locked in the value of either forward production or storage. The physical-market participants would likely have had physical assets against their derivatives positions so would have had little pressing economic need to unwind their trades at Amaranth's convenience. Michael Cosgrove, then president of Amerex Brokers, confirmed the identity of Amaranth's counterparties in Farrington (2006). "There were storage managers, pipeline companies and retail marketers who had absorbed the other side of the Amaranth position as hedges against their physical businesses," according to Cosgrove.

The time needed to unwind the Amaranth positions can be inferred by seeing if any footprints existed in natural gas price patterns from September 20, 2006 onward. Figure 2 on the next page shows the evolution of natural gas spreads in which the long legs are the winter contracts, and the short legs are summer and spring contracts, which in turn are collectively correlated to Amaranth's actual positions. The graph in this figure is from September 1, 2006 through December 31, 2006. This graph shows the spreads recovered in late September during the immediate aftermath of the portfolio transfer, indicating a (temporary) absence of liquidation pressure. At the end of September 2006, Citadel assumed the entire Amaranth portfolio, taking on J.P. Morgan's half of Amaranth's positions, by paying J.P. Morgan $725 million. Citadel also received all the remaining concessionary payments from Amaranth. As Figure 2 below shows, the natural gas spreads smoothly declined throughout October, and largely bottomed out by the end of October.

Figure 2
Natural Gas Spreads from September 1, 2006 through December 31, 2006



Source: Premia Research LLC.

Data Source: The Bloomberg.

Notes: NG is an abbreviation for natural gas. H and J are symbols for the March and April futures contracts respectively.

At the end of November 2006, widespread public reports existed about the contents of Citadel's bond prospectus, which provided some commentary on the timing of the unwinding of Amaranth's trades. The Citadel document said that the firm had reduced the risk of its Amaranth positions by two-thirds during the first two weeks of October. Given that the natural gas curve bottomed out at the end of October, an inference is that Citadel essentially finished reducing the risk of the remaining positions during the last two weeks of October. Commercial-market hedgers could have been the (ultimate) natural other side to Citadel's orderly unwind of October 2006 because they could realize their substantial hedging windfall at this time.

As Figure 2 shows, further liquidation pressure does not appear on the natural gas curve in November and December 2006. Given how stable the curve was during this time, this period is when normal two-sided flow likely resumed. Given how orderly Citadel's unwind was during October 2006, the firm probably only sustained relatively small losses during this time. Therefore, Citadel was apparently able to realize substantial net profits, given the $1.425 billion net payment that Citadel ultimately received for agreeing to take on Amaranth's distressed portfolio. [$1.425-billion = $2.15 billion (concessionary payment received by Citadel and J.P. Morgan) minus the $725 million that Citadel paid J.P. Morgan so that Citadel could fully take on the entire Amaranth energy portfolio and all remaining concessionary payments.]

Robert Greer, then of PIMCO, and now a Scholar-in-Residence at the University of Colorado Denver Business School's J.P. Morgan Center for Commodities, notes a key lesson from the Amaranth debacle. Hougan (2008) quotes Greer who said, "[T]he market showed that someone can actually be so big that the market will punish them, rather than reward them for their size."

We will conclude this article with the regulatory response to the Amaranth debacle, drawing from Till *et al.* (2018). Both the CFTC and the Federal Energy Regulatory Commission (FERC) pursued actions against the hedge fund, which were announced on July 25 and 26, 2007, respectively. Although the Senate report focused on whether Amaranth's position-taking pushed up the price of forward winter natural gas prices, the CFTC and FERC's investigations were much more narrowly focused on Amaranth's trading activities on several days of 2006, leading to allegations against Amaranth and its head natural gas trader of attempted and actual manipulation, respectively.

Zajac (2013) reports that "[i]n August 2009, … [Amaranth] agreed to pay $7.5 million to end U.S. cases brought by FERC and the CFTC over price manipulation. [Then] [o]n April 11 [2013], a federal judge in Manhattan gave final approval to a $77.1 million settlement by Amaranth to resolve a class action brought by traders."

The regulatory actions, in turn, against Amaranth's head natural gas trader became complicated by confusion about the FERC's authority over the U.S. energy futures markets. A federal court ruling finally resolved the matter on March 15, 2013. Zajac (2013) states that the U.S. Court of Appeals in Washington, D.C. ruled that the "'FERC lacks jurisdiction to charge … [Amaranth's head trader] with manipulation of natural gas futures contracts.' The Commodity Exchange Act gives the CFTC 'exclusive jurisdiction.'"

Van Voris and Hurtado (2014) report that a year-and-a-half later, on September 15, 2014, the former Amaranth trader "agreed to pay $750,000 to settle a Commodity Futures Trading Commission lawsuit claiming he tried to rig prices of natural gas contracts. … Under the agreement, which 'fully resolves' the commission's claims against him, … [the trader] also agreed to a partial ban on futures trading. … [The trader] neither admitted or denied wrongdoing."

Endnote

The author presented an abbreviated version of this paper on October 4, 2017 at a meeting of the Chicago chapter of the Professional Risk Managers' International Association, which in turn was hosted by William Blair Investment Management.

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Keywords

Amaranth, natural gas, regulatory.

From Grain to Natural Gas:
The Historical Circumstances That Led to the Need for Futures Contracts

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The article, "Brief Case Studies on Futures Contract Successes and Failures," which appeared in the Spring 2016 *GCARD*, summarized that there are three elements that determine whether a futures contract succeeds: (1) There must be a commercial need for hedging; (2) A pool of speculators must be attracted to a market; and (3) Public policy should not be too adverse. As noted by Kemp (2018), this type of analysis is useful for new financial centers when designing high-profile futures contracts.

In the current digest article, we will cover examples of successful contracts that responded to new large-scale commercial risks over the past 170 years. Each section below discusses the new commercial circumstances that ushered in the intense need for hedging instruments.

Chicago Became a Large-Scale Grain Terminal in the Mid-1800s

Once Chicago became a transportation hub and grain terminal in the mid-nineteenth century, grain merchants had to figure out how to manage the price risk for their accumulating volume of grain inventories. Eventually in 1848, the solution was the formation of an exchange: the Chicago Board of Trade, whose function gradually evolved from arbitrating commercial disputes and spot trading to bilateral forward trading, and finally to becoming a member-owned exchange with standardized futures contracts.

For further historical context, one should also note that "[b]y the time of the Crimean War in the 1850s, Chicago, with its rich outlying agriculture area, was in an excellent position to supply the disrupted world grain trade. During the [U.S.] Civil War, Chicago served as the chief grain concentration point of the Union armies," wrote Hieronymous (1971). And with the concentration of grain in Chicago came the need for managing the price risk of these immense inventories during the unpredictable times brought on by the two successive wars. Hence, a commercial hedging need arose that was met with the institutional development of a commodity exchange in Chicago.

The Collapse of the Bretton Woods System Ushered in a New Era of Financial Market Volatility

Examining the history of currency arrangements, in "the summer of 1944, delegates from 44 countries met in the midst of World War II [at Bretton Woods, New Hampshire to reshape] the world's international financial system," recounted Schifferes (2008). At this conference, John Maynard Keynes unsuccessfully floated the idea of an alternative post-war currency, the "Bancor," which was to be anchored by 30 commodities, a broader base than the Gold Standard. Instead, noted Conte and Karr (2001), "the leaders decided to tie world currencies to the dollar, which, in turn, they agreed should be convertible into gold at $35 per ounce." This created a modified gold standard. Therefore, when the

Bretton Woods system functioned, there was no pressing economic need for derivatives to hedge currency risk.

"In 1971, the US … unilaterally went off the gold standard and devalued the dollar … This led to the abandonment of fixed exchange rates and the introduction of floating rates, where the value of all the main currencies was determined by market trading," explained Schifferes (2008). With the U.S. dollar no longer pegged to gold or anything of fixed value, the risk of large price changes entered the markets. As reviewed by Leo Melamed, Chairman Emeritus of the Chicago Mercantile Exchange (CME) in Melamed (1994), "the collapse of the Bretton Woods Agreement … ushered in an era of considerable risk in currency price fluctuation – risks which could be limited if there were a viable market for currency futures trading." As a result, the Chicago futures exchanges developed innovative financial hedging instruments in both currencies and interest rates in the 1970s and 1980s. Equity index futures contracts were added in the 1980s. "[T]he economic benefits of risk transfer and price discovery that were indigenous to futures became available to those outside the agricultural sector," explained Melamed (1994).

Given that the launch of financial futures trading in Chicago did become hugely successful, it may be surprising to read about the early skepticism that greeted these efforts. According to Melamed (1994), "Some … thought it ludicrous that [in the early 1970s] a 'bunch of pork belly crapshooters' would dare" launch futures contracts on foreign exchange.

The Forced Shift to a Spot Oil Market

The volatile 1970s provide another example of new risks arising that were later successfully managed by the development of futures markets. In particular, Yergin (1992) recounted how the structure of the oil industry changed after numerous nationalizations in oil-producing countries in the 1970s. This forced some oil companies to shift from long-term contracts to the spot oil market. Verleger (2012) added that the U.K. government's choice of how to tax North Sea oil, starting in the 1970s, also contributed to the development of spot oil markets. "[T]he U.K. Treasury granted itself the right to decide the value of any oil processed by the company that produced it. Exxon, for example, would have been at the mercy of U.K. tax authorities had it processed crude from its fields. Rather than take such a risk, producers chose to sell their crude and then buy crude for processing from others. Their transactions created the first observable spot market for crude."

With the structure of the oil industry changing, an economic need for hedging volatile spot oil price risk emerged, which the New York Mercantile Exchange (NYMEX) responded to with a suite of energy futures contracts, starting with the heating oil contract in 1978.

According to Yergin (1992), "The initial reaction to the futures market on the part of the established oil companies was one of skepticism and outright hostility. … A senior executive of one of the … [major oil companies] dismissed oil futures 'as a way for dentists to lose money.' But the practice … [of] futures [trading] … moved quickly in terms of acceptability and respectability. … Price risk being what it was, … no [commercial entity] … could afford to stay out."

The Gradual Deregulation of the U.S. Natural Gas Market

The success of the petroleum-complex futures markets provided a precedent for how to manage the price risks of natural gas, once this market was deregulated.

In the past, the U.S. natural gas industry was so heavily regulated that there was no need for natural-gas-price hedging, analogous to the Bretton Woods fixed-rate era for currencies. The following is a brief recounting of the history of U.S. natural-gas regulation and deregulation, which is also conceptually illustrated in Figure 1 on the next page.

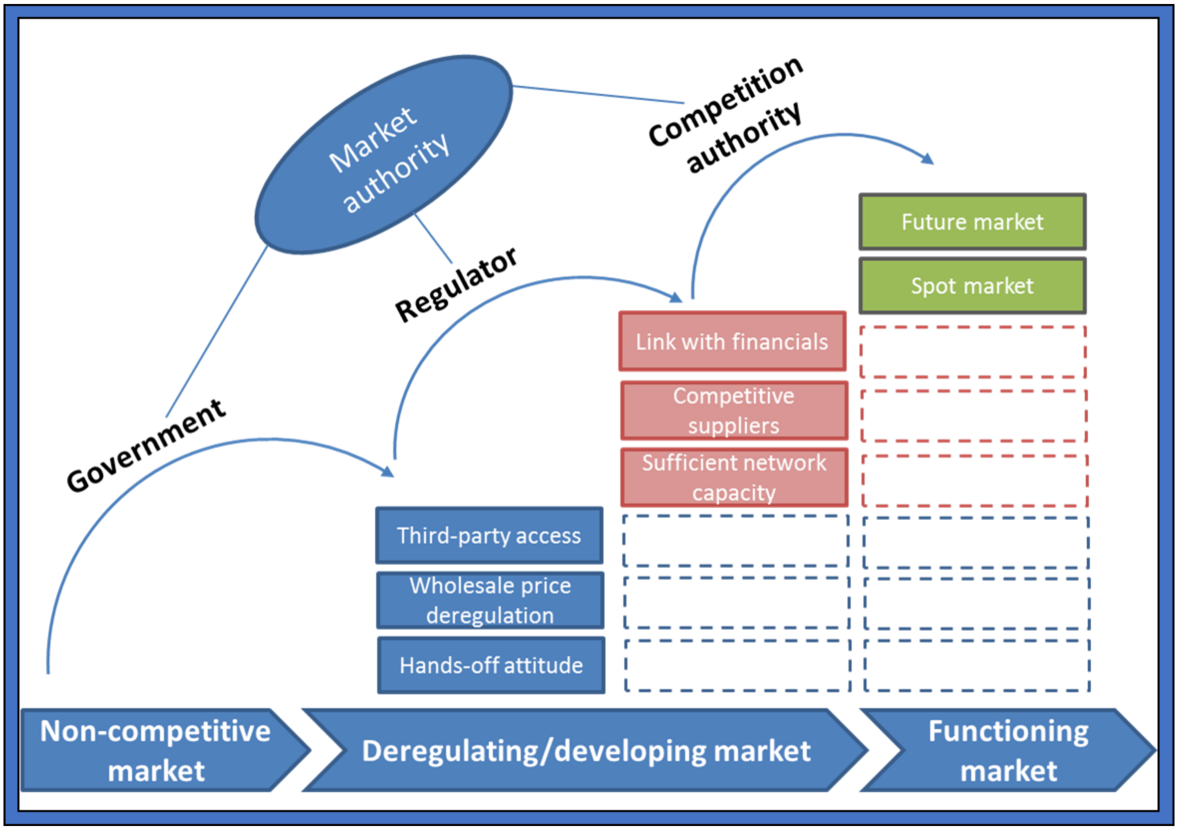
According to IEA (2012), the "1938 Natural Gas Act … introduce[d federal] regulation … on gas prices. The next four decades until 1978 saw a progressive growth of regulatory oversight of gas prices." In particular, "[t]he US system in the 1950s to 1970s" was one where "regulatory agencies controll[ed] most parts of the business in different parts of the gas value chain." Unfortunately, "[t]his heavy-handed regulation resulted in gas shortages appearing in the regions which needed to import gas from producing areas, notably in the Northeast and Midwest."

Starting in 1978, a very gradual deregulation of the U.S. natural gas market began. "In November of 1978, at the peak of the natural gas supply shortages, Congress enacted legislation known as the Natural Gas Policy Act (NGPA)," according to the Natural Gas Supply Association in NGSA (2013). "The Natural Gas Policy Act took the first steps towards deregulating the natural gas market, by instituting a scheme for the gradual removal of price ceilings at the wellhead," recounted NGSA (2013).

"However, it wasn't until Congress passed the Natural Gas Wellhead Decontrol Act (NGWDA) in 1989 that complete deregulation of wellhead prices was carried forth. Under the NGWDA, the NGPA was amended and all remaining regulated prices on wellhead sales were repealed. As of January 1, 1993, all remaining NGPA price regulations were to be eliminated, allowing the market to completely determine the price of natural gas at the wellhead," noted NGSA (2013).

Wrote Joskow (2013): "By the early 1990s, wellhead price regulation had come to an end, the intra-state and interstate markets had been integrated, the natural gas production sector was governed by competitive market forces, and gas shortages … disappeared. The natural gas market matured during the 1990s as liquid gas trading hubs … [including the] Henry Hub developed, [and] liquid spot, term, and derivatives markets [also] developed."

Figure 1
The Steps in Creating a Wholesale Natural Gas Market



Source of Schematic: IEA (2012), Figure 11.

Johnston (2002) explained that "[in] an important sense, exchange-traded contracts are a substitute for regulation in providing manageable stability in commodity prices, especially for energy."

Following the creation of a spot market in natural gas, the NYMEX "launched the first gas futures contract with delivery at the Henry Hub in April 1990," reported IEA (2012). "The trading activity related to financial gas markets has been increasing, enhanced by the development of internet and electronic trading systems over the past two decades. On the first day of trading on NYMEX, 918 contracts were traded compared to over … [350,000] today …. The futures were progressively expanded to 36 months in 1997 and to 72 months in 2001. Today futures reach until 202[5]," noted the IEA (2012)'s report. (Updated figures since the IEA (2012) report was written are shown in square brackets.)

Conclusion

Future issues of the *GCARD* will include digest articles on how successful futures contracts also (a) need to be able to attract speculators and (b) need a regulatory environment in which interventions are not too draconian.

Endnote

This digest article is excerpted from a seminar that was prepared for staff at the Shanghai Futures Exchange.

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Keywords

Bretton Woods system, futures contracts, crude oil, natural gas, hedging, regulation.

Geopolitical Risk and Commodities: An Investigation

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Introduction

World newsflow is frequently dominated by geopolitical risk, whether belligerent North Korean rhetoric and actions, the raging Syrian civil war, or the multifaceted situation in other parts of the Middle East. Meanwhile President Trump's election has seen the U.S. become increasingly insular, leaving a potential power vacuum in many parts of the world that strong-arm leaders such as China's President Xi and Russia's President Putin are seeking to exploit. Autocratic rulers are becoming more commonplace in other countries such as Turkey whilst populist parties are enjoying varying degrees of electoral success in many parts of Europe such as the Netherlands, Hungary, Poland, Italy and Greece. After more than half a century during which countries sought to become increasingly amicably interconnected, that trend now appears to be in reverse.

It is therefore notable that many of the world's commodity resources are located in countries generally considered less politically stable (LPS). For the purposes of this report we will define such countries as those ranked in the bottom two quintiles of the World Bank's Political Stability and Absence of Violence / Terrorism indices. Concentrations of reserves located in LPS countries are shown in Table 1 for various commodities (mostly metals) and vary from 28.9% for copper to 69.2% for oil. With the exception of copper, the proportion of reserves located in LPS countries is above 45%.

The second column of the table shows LPS production as a proportion of the total. The share of LPS production exceeds the share of LPS reserves for all commodities analyzed apart from oil.

The last three columns of the table illustrate the extent to which the developed world is dependent on LPS countries for the supply of the highlighted commodities:

- The proportion of reserves and production in and from LPS countries exceeds by some margin the share of global GDP represented by those countries;
- The U.S. relies on commodity imports to satisfy a variable but often significant proportion of its commodity consumption (in four out of eight metals U.S. import reliance is at least 75%);
- The U.S. imports a significant proportion of its commodities from LPS countries.

Table 1
Global Commodity Reserves Located in LPS Countries

	% of Reserves in LPS Countries	LPS Production as % of Total	% of Global GDP of LPS Countries	US Import Reliance as % of Consumption	% US Imports from LPS Countries
Bauxite & Alumina	51.0%	59.6%	34.6%	81.8%	29.9%
Copper	28.9%	40.2%	23.7%	34.0%	16.0%
Iron Ore	48.2%	57.5%	33.5%	12.1%	29.0%
Lead	47.7%	74.2%	33.5%	30.0%	25.0%
Nickel	46.4%	70.3%	28.5%	25.0%	8.0%
Oil	69.2%	60.4%	44.5%	-	-
Rare Earths	70.7%	89.0%	24.0%	100.0%	63.0%
Tin	83.5%	92.7%	29.1%	75.0%	31.0%
Zinc	45.4%	68.6%	28.1%	82.0%	72.0%

Sources: World Bank, IMF, U.S. Geological Survey, EFG calculations.

Given the potential for LPS country and regional instability to disrupt commodity supplies, it is surprising that so little has been written regarding the linkages between geopolitics and commodity prices. Moreover, what has been written generally concentrates on the impact of geopolitics on oil. Hughes and Lipscy (2013) provide a useful overview of the literature on the subject.

Focusing on the potential for supply side disruption due to geopolitical events seems natural, although doing so implicitly assumes a chain of causality from geopolitical instability to supply shocks to prices. Yet the direction of causality is questionable.

One narrative evolves around an exogenous geopolitical shock precipitating a spike in certain commodity prices. An alternative narrative describes a world in which commodity price changes breed economic instability which in turn is a factor in generating or amplifying geopolitical uncertainty. For example, the reliance of many Middle Eastern countries on oil export revenues, as shown in Table 2, is well known.

Table 2
Oil Reliance: General Government Fiscal Balances

	Non-Oil Fiscal Balance as % of Non-Oil GDP		Fiscal Balance as % of GDP	
	Projections		Projections	
	2017	2018	2017	2018
MENAP Oil Exporters	-28.0%	-25.5%	-5.7%	-4.6%
Algeria	-20.4	-17.7	-3.5	-1.2
Bahrain	-30.6	-28.5	-13.2	-11.9
Iran	-11.3	-10.6	-2.2	-2.2
Iraq	-49.9	-45.1	-5.1	-4.7
Kuwait	-55.5	-54.4	1.5	1.5
Oman	-44.5	-41.7	-13.0	-11.4
Qatar	-26.6	-22.6	-1.0	0.5
Saudi Arabia	-35.9	-32.6	-8.6	-7.2
United Arab Emirates	-18.3	-16.1	-3.7	-2.2
Yemen	-13.6	-15.9	-9.9	-6.6
CCA Oil and Gas Exporters	-17.6	-12.9	-3.3	-0.7
Azerbaijan	-29.5	-25.7	-0.3	0.7
Kazakhstan	-16.0	-10.3	-6.6	-2.0
Turkmenistan	-5.6	-4.7	-1.1	-0.1

Source: *IMF Regional Economic Outlook: Middle East and Central Asia*, October 2017.
Abbreviations: MENAP stands for Middle East, North Africa, and Pakistan; and
CCA stands for Caucasus and Central Asia.

The term, "Dutch disease," is often used to describe such a narrative, whereby a country becomes overly reliant on exports of a commodity with which it is naturally endowed; when the price of that commodity drops the country suffers an outsized negative shock.[1] An important question therefore relates to the direction of causality between geopolitical uncertainty and commodity prices.

This paper seeks to explore these issues in an attempt to answer the question. The next section discusses how to define and measure geopolitical uncertainty. Having found an appropriate metric, a vector autoregressive (VAR) model is estimated to address the fundamental research question highlighted above. Results are then presented and discussed.

Measuring Geopolitical Risk

Geopolitical risk is hard to define, or at least to do so in a precise way. It is therefore also hard to measure. And without measurement, we can't perform statistical analysis.

Numerous attempts over the years have attempted to define and measure geopolitical risk, with varying degrees of success. Geopolitics for Investors written by Pippa Malmgren for the CFA Institute Research Foundation provides an excellent discussion across a broad range of pertinent issues. In it she notes, "No one can accurately predict what will happen on the geopolitical landscape. But as part of their fiduciary responsibility, fund managers can and should assess how much value is created by geopolitical stability or destroyed by geopolitical instability."

For investors to be able to assess the impact of geopolitics on the investment outlook there are two broad approaches: (i) subjective and (ii) quantitative. The subjective approach requires a variety of inputs from which a holistic assessment can be made. Such approaches are typically enormously time consuming, involving as they do the collection, collation, assessment and interpretation of large amounts of information, much of which is not quantitative. Margolis (2012) describes such an approach as used by the CIA. The quantitative approach relies on the generation of indices that seek to express in a single number the degree of risk inherent in a particular country or region. Whilst it takes time and effort to construct these quantitative indices, they are highly convenient for the user from an analytical perspective since the information is encapsulated in a single data point that can be quickly and easily utilized.

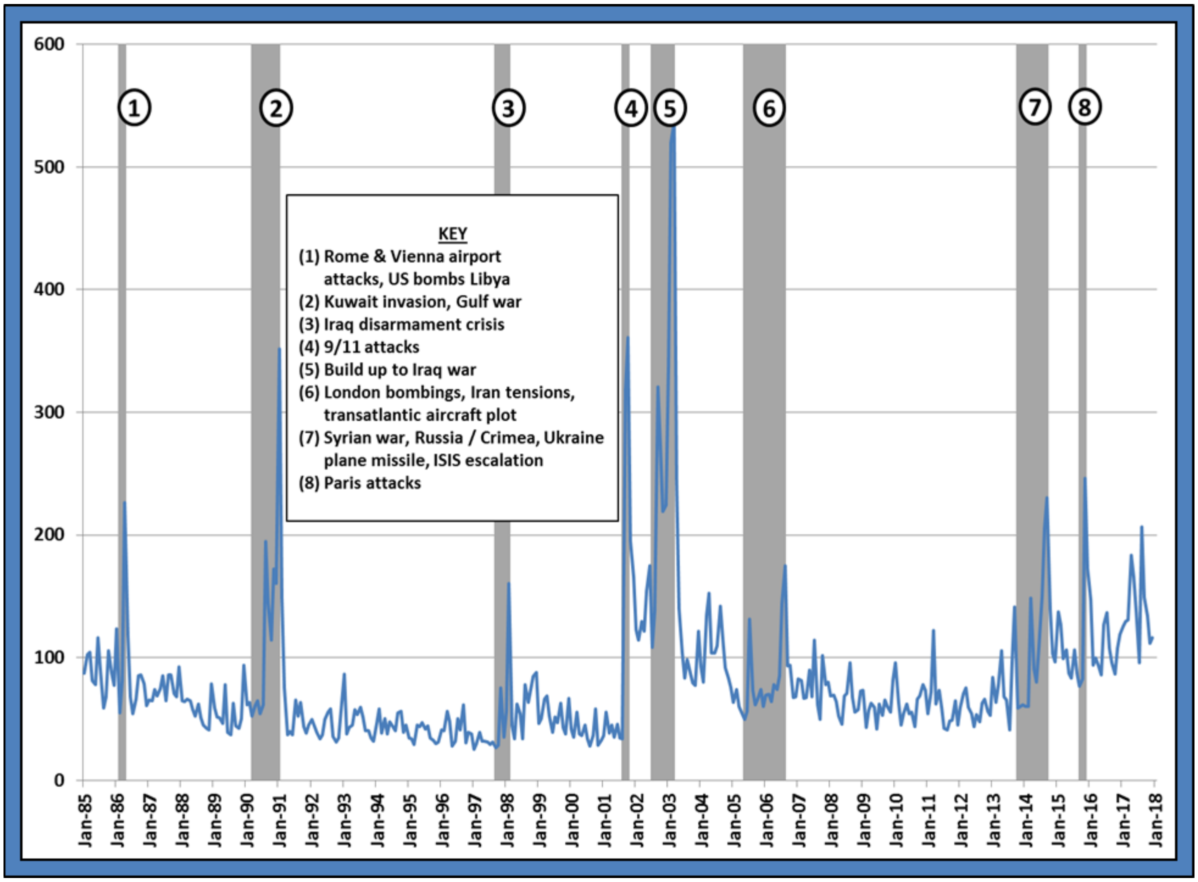
The World Bank index mentioned above is an example of one such quantitative measure. Other examples include the Political Instability Index produced by the Economist Intelligence Unit, the Index of State Weakness from the Brookings Institute, the Fragile States Index by the Fund for Peace, Predata's Geopolitical Volatility Index and the State Fragility Index from the Centre for Systemic Peace. All have their merits and limitations. Some are updated irregularly or infrequently whilst others have limited history. Many share similar methodologies that rank countries – sometimes subjectively – across different dimensions such as political, economic and social factors and then combine these metrics into an aggregate index.

The output from these indices rarely produces any surprises: it simply confirms what we already know. Countries generally perceived as being riskier have the worst scores whilst the top ranks are dominated by so-called developed world countries. For the purposes of answering the research question central to this report, such indices are of limited use. For a geopolitical risk index to be useful for the desired analysis, we need a long history of regularly and frequently updated data that is limited in terms of its subjective influences. The index also needs to be freely and easily available. It is fortunate that two Federal Reserve economists have recently produced an index fitting this description.

Caldara and Iacoviello (2017) produce geopolitical risk (GPR) indices based on the count of certain words in the media, specifically within 11 internationally recognized and respected English language newspapers. Technology facilitates relatively straightforward production of the index (and sub-indices) since the word search can be conducted electronically. Electronic records for all 11 newspapers start in

1985, which is when the index begins. A longer running version starting in 1900 can be produced using electronic records for three of the publications. Figure 1 shows the full index from 1985.

Figure 1
Geopolitical Risk Index (GPR)



Source: Matteo Iacoviello's website (https://www2.bc.edu/matteo-iacoviello/gpr.htm#data).

It is notable that the GPR index has been in a rising trend over the past few years, reflecting in a quantitative way the discussion in the opening paragraph. Whilst there have been occasional spikes since the lull in the early 2010s, none have matched those seen in the early 2000s or early 1990s in terms of scale.

Preliminary Analysis

A preliminary and informal analysis of the relationship between the GPR and different financial indices is shown in Table 3. Each row in the table represents a period during which the GPR spiked, as highlighted in Figure 1. For example, the row representing the period from March 1990 to January 1991 reflects the spike in geopolitical risk associated with Iraq's invasion of Kuwait and the ensuing Gulf War. Data for the VIX index of implied volatility begins in 1990.

Table 3
The GPR and the Behavior of Financial Indices

	Start	End	Change in GPR	Percent Change in: WTI Oil	Gold	GSCI	S&P 500	DXY	Change in VIX	Change in T10 Yield
1	Feb-86	Apr-86	179.4	0.8%	2.2%	0.4%	3.8%	-2.6%	-	-8.0%
2	Mar-90	Jan-91	326.7	7.8%	-0.7%	-2.1%	1.2%	-12.6%	1.2%	-6.2%
3	Sep-97	Feb-98	140.1	-26.8%	-10.4%	-18.2%	10.8%	2.8%	-4.4%	-4.8%
4	Aug-01	Oct-01	330.9	-22.1%	2.0%	-13.6%	-6.5%	1.3%	8.6%	-6.0%
5	Jul-02	Mar-03	416.7	14.9%	11.1%	14.2%	-7.0%	-7.9%	-2.9%	-6.6%
6	May-05	Aug-06	119.6	35.2%	50.2%	31.3%	9.4%	-3.1%	-1.0%	7.4%
7	Oct-13	Sep-14	165.5	-5.4%	-8.7%	-7.7%	12.3%	7.2%	2.6%	-0.7%
8	Sep-15	Nov-15	176.2	-7.6%	-7.6%	-6.5%	8.4%	4.0%	-8.4%	1.7%
	# Occasions the Index Rallied			4	4	3	6	4	3	2
	# Occasions the Index Sold Off			4	4	5	2	4	4	6

WTI = West Texas Intermediate
DXY = Trade weighted US dollar
T10 = ten year US Treasury bond
GSCI = Goldman Sachs Commodity Index
VIX = implied volatility index

Sources: Caldara and Iacoviello (2017), Bloomberg, EFG calculations.

The last two rows of the table provide a count of the number of times each of the different financial indices rallied and sold off. For the purposes of clarity, a rally in the VIX signifies an increase in implied volatility whilst a rally in the T10 note yield represents a sell-off in the Ten-Year Treasury note (an increase in yield). An environment of heightened geopolitical risk might reasonably be expected *a priori* to be associated with increases in oil, gold, the VIX and the Ten-Year Treasury note (declining yield) with a sell-off anticipated in the S&P500. However, the simple count analysis shows the results are far from clear cut. Furthermore, not only are the moves often relatively small with no clear directional bias, but it is also true that in some instances the movement is in the opposite direction to that anticipated.

Thus, the S&P500 index has rallied on more occasions than it has sold off whilst a related observation is that the VIX index declined on more occasions than it increased. Perhaps the only financial metric to have behaved broadly as expected is the Ten-Year Treasury yield, which has indeed demonstrated a tendency to decline when the GPR has spiked. With regard to commodities, the GSCI data is inconclusive, rallying on some occasions and selling off on others, often by quite large orders of magnitude in both directions.

This simple analysis suggests there is some ambiguity regarding the relationship between geopolitical risk and financial indices. However, the analysis focusses on only eight specific periods and does not investigate issues related to causality nor how the variables respond to shocks. This latter point is of particular interest given the volatile and unpredictable nature of geopolitical risk. To investigate these issues we have performed a vector autoregressive (VAR) analysis, which is discussed in the next section.

VAR Analysis

There are three pertinent questions in which we are interested:

(i) What, if any, is the causal relationship between geopolitical risk and commodity prices?
(ii) Has the nature of the relationships changed since the global financial crisis (GFC)?
(iii) How do the variables respond to shocks?

To answer these questions a VAR analysis was performed using the following variables:

(1) GPR $GSCI_i$ VIX SP DXY T10 IP

Where:

GPR = Global Political Risk index	VIX = implied volatility index
SP = S&P500 index	DXY = trade weighted US dollar
T10 = Ten-Year U.S. Treasury yield	IP = U.S. industrial production

And $GSCI_i$ represents the aggregate and sub-indices of the S&P Goldman Sachs Commodity Index (GSCI) where i = T (Aggregate), AG (Agriculture), EN (Energy), IND (Industrial Metals), LIVS (Livestock) and PM (Precious Metals)

All variables are expressed in log differences apart from GPR and VIX which are in levels. All variables are stationary after transformation.

The VIX term is included to take into account general market risk as distinct from geopolitical risk. The SP, DXY and T10 terms are included to allow for interaction between the variables and financial markets whilst the IP term represents the broad U.S. economic cycle. Each model formulation was estimated using monthly data over three time periods: Whole Sample is from January 1990 to November 2017; Pre-GFC is from January 1990 to December 2007; and Post-GFC is from January 2008 to November 2017.

Granger Causality

The primary relationship in which we are interested in this paper is that between commodities and geopolitical risk. For the sake of brevity and ease of interpretation Granger causality test results related only to that relationship are shown in Tables A1a-f in Appendix A.

There are a number of interesting results:

- There appears to be no Granger causality in either direction between $GSCI_T$ and GPR although the relationship appears to be stronger from $GSCI_T$ to GPR than the other way round.
- However, the analysis suggests that $GSCI_T$ did Granger cause GPR pre-GFC but that the relationship has subsequently broken down.
- Performing similar analysis using the commodity sub-indices shows that:

- Over the whole sample, evidence of Granger causality is found from $GSCI_{IND}$ to GPR and from GPR to $GSCI_{LIVS}$.
- Pre-GFC there is evidence of Granger causality from $GSCI_{IND}$ and $GSCI_{EN}$ to GPR and to a lesser extent from $GSCI_{PM}$ to GPR.
- Pre-GFC there is also some evidence in support of Granger causality from the GPR to $GSCI_{LIVS}$ and $GSCI_{PM}$.
- Post-GFC there is evidence of Granger causality from $GSCI_{PM}$ to the GPR but not for any other commodity sub-index.
- Post-GFC there is no evidence in support of Granger causality from the GPR to any of the commodity sub-indices.

Impulse Responses

Impulse response functions (IRFs) from GPR to $GSCI_i$ and from $GSCI_i$ to GPR are shown in Appendix B. In all cases the Cholesky ordering follows the order of variables shown in (1) above. The charts show the impact of a one standard deviation shock to GPR on $GSCI_i$ and also the impact of a one standard deviation shock to $GSCI_i$ on GPR. The results are summarized as follows:

- Shocks to the various $GSCI_i$ indices do not appear to have much of an impact on GPR. In all cases across almost all time periods the ±2 standard error range encapsulates 0.
- The message is less clear cut in terms of the impact of a 1 standard deviation GPR shock on $GSCI_i$. In three out of six instances there appears to be little impact ($GSCI_{AG}$, $GSCI_{IND}$, $GSCI_{LIVS}$).
- However, a shock to GPR appears to impact positively $GSCI_T$ and $GSCI_{EN}$ and, to a lesser extent, $GSCI_{PM}$.

Discussion and Conclusions

This paper has investigated the relationship between geopolitical risk and commodity prices, something on which there is a notable dearth of academic literature. A possible reason why the literature is lacking in this regard is that the measurement of geopolitical risk is not straightforward. What is more, even though several measures do exist, they do not easily lend themselves to statistical enquiry. The recently produced GPR index remedies many of the issues associated with other such metrics, permitting much easier analysis. A simple event study of the relationship between this measure of geopolitical risk and financial indices suggests that periods during which geopolitical risk spikes are associated with ambiguous movements in those indices. Moreover, the direction of some of the moves is contrary to what one might have anticipated.

A VAR analysis allows deeper investigation of the relationships. It is interesting to note that there is evidence of Granger causality from commodity prices to the geopolitical risk index in the years preceding the GFC but not afterwards. One can speculate as to why that might have been: to what extent were commodity prices and geopolitical risk impacted by the enormous strains on the financial system that engulfed the world during the GFC? And what was the impact of the unprecedented monetary policy response that followed and which is only now slowly being reversed? Under what conditions might we expect that causal relationship to reassert itself? Furthermore, to what extent have the fundamental supply-and-demand conditions for commodities changed over the years, for example due to the trend towards cleaner energy or the rise of China? These are all interesting questions for future work.

Impulse response analysis is not particularly revealing. It suggests some impact from a geopolitical shock to commodity prices and in particular energy prices. This perhaps reflects the observation made in the introduction that the world is highly dependent on oil from LPS countries. There is little to highlight other than that. This is perhaps interesting in itself because it is in contrast with commonly held views about the impact of heightened geopolitical risk on certain financial markets.[2]

In addition to the questions highlighted above, there are a number of other issues worthy of further investigation. For example, it is known that differences exist in the timing of production and consumption cycles associated with various commodities and also that there are regional biases. It may be that incorporating such factors into the analysis enhances the work. That may necessitate a more granular approach to thinking about commodities - in this paper high level indices have been used but it would be interesting to explore the usage of individual commodity prices in the analysis. Similarly, it may also be informative to examine relationships between the slope of commodity futures curves and geopolitical risk.

One further thought is that the analysis has focused on short term relationships between the various indices. However, at least in some instances geopolitical risk takes several years to evolve before it erupts. It would therefore also be interesting to explore the longer term dynamics of geopolitical risk and its relationship with commodity markets.

A final comment relates to the underlying nature of geopolitical risk and its interaction with financial markets. Surges in geopolitical risk tend to be events with unique characteristics, some of which require a policy response but many of which don't. Hence, the reaction of financial markets to a geopolitical event will depend to some extent on the nature of the policy response.

Appendix A: Granger Causality

The numbers in the tables represent probabilities that the Null (dependent variable is not Granger caused by the explanatory variables) cannot be rejected. A high (low) probability signifies that the Null cannot (can) be rejected.

Table A1a. Granger Causality: Geopolitical Risk and Commodities

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_T$	GPR	$GSCI_T$	GPR	$GSCI_T$
Explanatory	GPR		0.3832		0.2157		0.8909
	$GSCI_T$	0.110		0.0129		0.9701	

Table A1b. Granger Causality: Geopolitical Risk and Agricultural Commodities

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_{AG}$	GPR	$GSCI_{AG}$	GPR	$GSCI_{AG}$
Explanatory	GPR		0.6283		0.3163		0.9487
	$GSCI_{AG}$	0.8572		0.9114		0.6434	

Table A1c. Granger Causality: Geopolitical Risk and Energy Commodities

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_{EN}$	GPR	$GSCI_{EN}$	GPR	$GSCI_{EN}$
Explanatory	GPR		0.2471		0.2548		0.9186
	$GSCI_{EN}$	0.1667		0.0369		0.9927	

Table A1d. Granger Causality: Geopolitical Risk and Industrial Metals

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_{IND}$	GPR	$GSCI_{IND}$	GPR	$GSCI_{IND}$
Explanatory	GPR		0.6993		0.2845		0.2735
	$GSCI_{IND}$	0.0200		0.0002		0.9671	

Table A1e. Granger Causality: Geopolitical Risk and Livestock Commodities

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_{LIVS}$	GPR	$GSCI_{LIVS}$	GPR	$GSCI_{LIVS}$
Explanatory	GPR		0.0477		0.0371		0.7013
	$GSCI_{LIVS}$	0.2127		0.6504		0.6572	

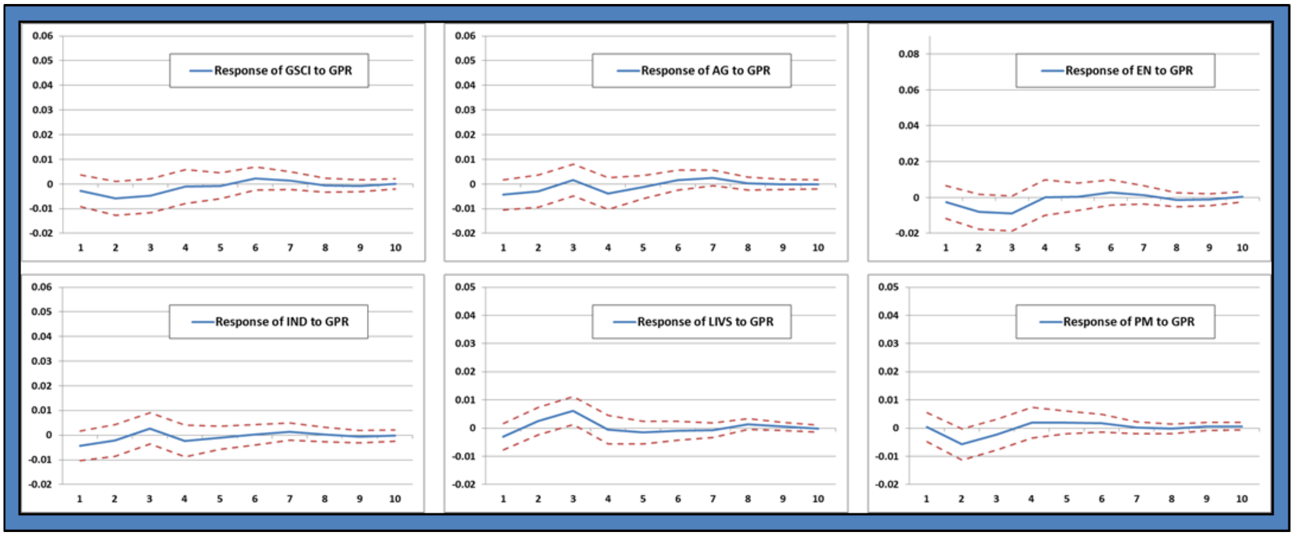
Table A1f. Granger Causality: Geopolitical Risk and Precious Metals

		Jan-90 to Nov-17		Jan-90 to Dec-07		Jan-08 to Nov-17	
		Dependent		Dependent		Dependent	
		GPR	$GSCI_{PM}$	GPR	$GSCI_{PM}$	GPR	$GSCI_{PM}$
Explanatory	GPR		0.0760		0.0563		0.6471
	$GSCI_{PM}$	0.1258		0.0795		0.0491	

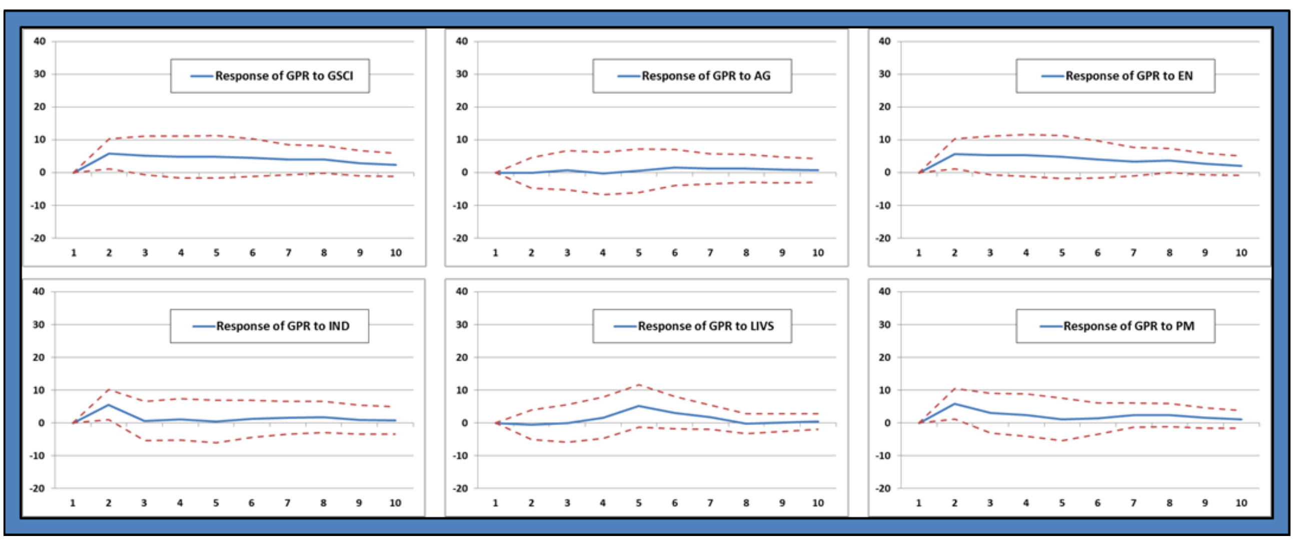
Appendix B: Impulse Responses

Blue lines show the central estimate in response to a one standard deviation shock. Red lines show ±2 standard errors around the central estimate.

Impulse Response Functions from $GSCI_i$ to GPR:



Impulse Response Functions from GPR to $GSCI_i$:



Endnotes

1 See "The Dutch Disease," *The Economist*, November 26, 1977 or Corden (1984).

2 A quick internet search for the term, "geopolitics and commodities," delivers a slew of results propagating the belief that geopolitics is a major factor in driving commodity prices. See for example, "Oil Prices are at the Mercy of Geopolitics," by Daniel Yergin, *Financial Times*, January 20, 2016; "Geopolitics and Uncertainties Keep Gold Gurnished," by Andrea Soh, *The Business Times*, September 26, 2017; or "Commodities: The Need for Geopolitical Perspective," from *Bloomberg*, May 28, 2015.

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The History of a Supply-Driven Bear Market: Part 2 of 2
Oil Price Surprises from 2016 Onwards

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Introduction

This article is the second in a two-part series. This series of articles provides insights into the complex dynamics of oil price formation from 2014 onwards. Part 1, which was in the last issue of *GCARD*, focused on the events influencing the oil markets from 2014 through 2015 while Part 2 covers (a) oil-market-moving events from 2016 through the present and near future and (b) JOSCO Energy Finance and Strategy's field-by-field oil production analysis through 2025.

Oil price formation is characterized by highly dynamic interactions amongst a wide set of drivers, each one sometimes dormant, and at other times, hyperactive. These drivers can be clustered into four overarching categories: (1) Supply & Demand Fundamentals, (2) Geopolitics, (3) Geo-Finance, and (4) Technology & Innovation. The reader will recognize them all in this article. The latter captures climate change and the energy transition. The third, Geo-finance, includes two branches: the first around macroeconomic parameters such as the dollar exchange rate, interest rates, inflationary expectations, trade balances, and debt levels. The Fed, ECB, Bank of Japan, Bank of China and Bank of England all play a pivotal role in this. The second branch includes fast-cycle money invested in oil through futures and options traded on the New York Mercantile Exchange (NYMEX) and the Intercontinental Exchange (ICE), as well as on the Dubai Mercantile Exchange and as of March 26 of this year, also on the Shanghai International Energy Exchange.

Oil, like all commodities, is not an anticipatory asset, and pricing expectations typically prove self-negating. Hence, in contrast to equities, oil does not have much expectation value and is thus, far more of a spot asset class. For that reason, big structural changes, such as we witnessed in 2014, always seem to come as a surprise, as did the recent spike in Brent oil prices from $47 a barrel in mid-June of last year to $61 in early December and $70 in late January 2018, only to fall back to $62 a barrel in the second week of February 2018. With the arrival of shale oil in the U.S., trading in paper oil (futures contracts) has exploded since 2010 and brought a new group of macro funds, hedge funds and other speculators to the market in recent years.

The oil price went through a full cycle during the years 2014 through 2017. During this time, the oil curve went from backwardation in the first months of 2014 to a situation where spot prices started to fall in the 2nd half of 2014 when the curve shifted in contango. Subsequently, long-dated prices started to fall as well while the front of the curve went into even steeper contango. Halfway through the cycle, the curve started to flatten at which point spot prices started to recover. Finally, in the 2nd half of 2017, the curve flipped back into backwardation while long dated prices also started to rise, signaling a normalization of the market. The big question now is whether the "New Oil Order" brought on by the

North American shale oil revolution is on hiatus. Moreover, who are the winners? And who are the losers? And have price discovery and the price formation process really changed?

2016

Oil prices were falling fast in 2016. Energy option prices were outpacing the decline in oil prices, showing that investors were increasingly concerned about the potential for oil price declines to accelerate. The oil market appeared to be approaching the end game. The resilience of non-OPEC production ex U.S. continued to be a major factor in oil market oversupply while OPEC production remained close to the highs of the year at 31.7 million barrels per day (mb/d). Moreover, the International Atomic Energy Agency had announced on January 16 that it had verified that Iran had implemented its nuclear-related measures described in the Joint Comprehensive Plan of Action, which allowed Iran to resume oil exports to all non-U.S. destinations. There was a rising probability that storage would run out of capacity soon. The Brent 1-6 month time spreads widened to incentivize floating storage, a very bearish scenario; and the possibility of oil prices hitting cash costs came into sight.

The supply response was now resting on two short-cycle sources of supply: U.S. shale and OPEC. Mid-January, it was estimated that U.S. shale production would decline 500-600 thousand barrels per day (kb/d), driven by tighter financial conditions at lower oil prices. This would be much more than the extremely modest -150,000 b/d decline year-over-year as of year-end 2015. Meanwhile the cost deflationary spiral continued, not only in the U.S. but elsewhere. The key theme for 2016 was a real fundamental adjustment occurring, which would rebalance markets and eventually create the birth of a new bull market. Spot oil prices shot below $30/barrel (bbl) to $27/bbl. With spot prices reaching a bottom, the next step would be for participants in the futures market to sell off the back-end of the futures curve in the coming months, and then shrug off the bear market that had been going on since the summer of 2014. A flat curve near cash costs is historically the buy signal for passive investors, and it was plausible that this bear market would end in the same way. While we already noted at that time that "you should never catch a falling knife," we now saw the moment that "the knife had landed ... and that it was the best time to enter the market again."

Newspapers were suggesting that OPEC producers and Russia would meet in February to discuss a potentially coordinated cut in production. However, such a cut was also seen as a self-defeating action given the short-cycle of shale production and therefore was not given a high possibility of occurring. But only signaling the market resulted in a 7% price rally, which took 1-month oil price volatility to 70%, its highest level since April 2009. According to one report, "OPEC was best off to sustain production and let the market do its work, as that would maximize revenues medium term." But should a cut occur, oil prices would only get support from such a step once inventories stopped building. With oil prices approaching stress levels, this was expected to pressure U.S. shale producers into restraining production, which would thereby prevent storage tanks from overflowing.

Different from expected, Saudi Arabia, Russia, Qatar and Venezuela announced on February 16 that they had agreed to freeze oil production at their January level, but only if other producers would commit as well. This was the first coordinated production decision between OPEC and non-OPEC members in fifteen years and it was said that "other steps to stabilize and improve markets" could follow. However, this announcement did not immediately have an impact on prices. By March 11, the average price for West Texas Intermediate (WTI) year-to-date was still \$32/bbl driven by new records for storage utilization close to a saturation point. Fortunately for stabilizing the price of oil, U.S. Lower-48 production was further declining and supply disruptions within OPEC were rising to more than 2 mb/d in unplanned outages, mainly due to Libya, Iraq and Nigeria, while Venezuela's production was in structural decline. Also, only a modest increase in Iranian production of 280 kb/d was foreseen (much lower than the 600 to 800 kb/d this author personally forecasted at that time.) Meanwhile, time spreads in WTI and Brent had strengthened, indicating that inventories were drawn more than seasonally during the winter months. Taking all things together and highlighting that this remains a supply-driven bear market, price forecasts were lowered to \$35/bbl for 2Q2016, gradually rising to \$40/bbl in 4Q2016 and \$50-60/bbl in 2017. "Such price improvement in the next 18 months would be driven by near-dated prices with a return to backwardation by late 2016. Sequential U.S. production growth would be required, but only from 2Q2017 onwards," according to one investment bank report. However, based on curve movements in the 1998-2000 period and the time it took to move from deep contango back to backwardation - a sign of a normalization in the oil markets - a prediction of a return to backwardation by late 2016 was extremely optimistic, perhaps even unrealistic. Normalization in the oil markets would definitely take longer, most likely not earlier than the 2nd half of 2017. Only a coordinated action by OPEC could accelerate such process. Meanwhile high demand growth stimulated by lower oil prices, quantitative easing, and a gradual improvement of world economies would do their work.

On April 17, OPEC and non-OPEC producers met again in Doha. The biggest hurdle to reaching any meaningful agreement was the conflicting Saudi and Iranian stances with Iran repeatedly having stated that it would continue to grow production and regain market share. No positive surprises came out of the meeting. Nevertheless, oil prices continued to recover to \$50/bbl in June. However, fundamental volatility as a result of unplanned outages continued to create an uncertain path for oil rebalancing. While the physical barrel rebalancing had started, the industry was still adjusting, which led to a lower 2017 forecast with prices in 1Q2017 at \$45/bbl and only reaching \$60/bbl by 4Q2017. In the last week of May, the U.S. oil rig count reached its lowest level at 316 rigs (vs. a peak of 1,609 reached on October 10, 2014.) As in previous downturns, the crude oil glut had also become an oil product glut, as refineries were incentivized to run higher than normal utilization.

Another OPEC meeting took place in Algiers on September 26-28. After six failed attempts, and a new Saudi Arabian energy minister, a deal to curb production later in the year became more likely than at any point in the past two years. After having given up the price formation role during the last two years and after having recognized that some market orchestration would be required for inventories to decline to normal levels, and preferably at a faster pace, Saudi Arabia was determined to force the others into a deal that it could live with, knowing that it most likely had to give major players an exemption. The Kingdom played hard ball this time, determined to earn back its reputation as the "central bank for oil." Instead of just walking out of the meeting without any consequences for the other members as happened in November 2014, this time it threatened to blow up OPEC completely if no deal would be reached at the next Ministerial meeting in November. Moreover, Saudi Arabia was sufficiently motivated by its price-volume elasticity advantage to agree to an OPEC deal. More precisely, market volatility associated with OPEC meetings gave them confidence that if a deal could be structured, the lost production would result in higher revenues without losing market share. This was the turning point. However, this was not leaked to the outside world at that time, and some analysts saw prices still skewed to the downside. In some cases, year-end forecasts were lowered materially at the time of the Algiers meeting on the back of potentially fewer disruptions and the relatively high speculative long positions. Low cost production continued to surprise to the upside, at that time in Saudi Arabia and the UAE, previously in Iraq and Iran, and next in Russia. Also, the ramp-up in new production outside of OPEC was set to accelerate with 2017 additions from new projects sanctioned before the summer of 2014 expected to be 30 percent higher than in 2016. In addition, legacy production declines had remained limited outside of China, Venezuela, Columbia and Mexico as producers were seeking to maximize cash flow from existing production. In turn, U.S. production declines were set to slow with the oil rig count up 31 percent since the trough, and the aging U.S. shale well profile showing stabilizing production.

Nevertheless, the post-Algiers rally in oil prices continued, fueled by comments by Saudi Arabia and Russia that pointed to a greater probability of reaching a deal to cut production. But as usual, risks of disagreement were not negligible with Iran, Iraq, Nigeria and Libya the most vocal opponents. All were aiming to grow production in 2017 and were disputing the usual measures of its production as too low. But ultimately Saudi Arabia had a strong incentive to cut production to achieve a normalization in inventories in anticipation of the Saudi Aramco IPO and in light of its deteriorating budget. Moreover, an agreement with Russia would (hopefully) end the highly competitive battle for market share in Asia, notably in China. This was mainly driven by the following three important factors. First, a sharp devaluation of the rouble vs. the dollar from about 34 in June 2014 to a peak of 81 early in 2016 before stabilizing around 60 for the year had improved oilfield economics in Russia fabulously, as most operational and conventional drilling costs are predominantly or completely set in roubles. Saudi Arabia, with its currency pegged to the dollar, was harmed by dollar strength, and thus saw its relative competitive position vs. Russia deteriorating. Second, the imposition of Western financial and other sanctions, which were levied as a result of events in the Ukraine and Russia's retaking of Crimea, resulted in China stepping in to provide pre-export finance to Russian oil companies to replace Western credits that had to be refinanced. Third, these credits backed by oil export flows enabled Russia to leapfrog over Saudi Arabia to become the dominant provider of oil to China, using in the best possible way its expanded network of pipelines from Eastern Siberia to China and from Western Siberia via Kazakhstan to China. The combination of these factors helped Russia achieve its longstanding goal of moving from a lumpy passive supplier of oil and gas to Europe to assume a much more active role in influencing world oil markets economically as well as politically. Thus for Saudi Arabia, accommodating U.S. shale was already a formidable challenge, but now it was also being challenged by the 2nd largest producer.

On November 30, OPEC members agreed to cut OPEC production by 1.2 million b/d from October levels to 32.7 mb/d for six months starting in January. The deal achieved a broad consensus with Libya, Nigeria and Indonesia exempted, a modest growth allowance for Iran based on secondary sources and a 4.6% cut across other producers. Discussions with other non-OPEC producers would continue and indeed on December 10, eleven non-OPEC producers agreed to join eleven OPEC members to reduce production by 558 kb/d in 1H2017. Russia agreed to contribute 300 kb/d. The goal would be the normalization in inventories rather than achieving much higher oil prices, which would instead unleash a sharp production response in the U.S. The big question became in how far participating countries would comply. In general compliance levels were set quite high by market analysts, in the order of 85% to the headline cut of -1.6 million b/d (-1,164 kb/d announced by OPEC and -458 kb/d by non-OPEC participants), and much higher than historically achieved. The biggest issues were the possibility of a potential ramp up in Libya and Nigeria. But overall, it was expected that the global market imbalance would finally turn into a deficit in every quarter of 2017. After inventories normalized in 2017, the common view was - and still is - that OPEC and Russia would return to high production levels. However, one could argue, also on the abovementioned factors, that Core Gulf OPEC and Russia ("ROPEC") will be a much stronger bond than currently foreseen, and would stay there for much longer.

The shale revolution and the ensuing flattening of the oil cost curve with no imminent need for sanctioning "Most Expensive Oil" projects has driven important shifts in the sources of future supply, as covered in Part 1 of this series. While historically during the investment phase, large "Cheap Oil" producers like Saudi Arabia and other Gulf OPEC countries could impact the long-term oil price when the oil cost curve was steep (by choosing a value strategy instead of a volume strategy), they become price takers once the cost curve flattens and new "Most Expensive Oil" developments are no longer necessary. This would lead them to develop new strategies around actively managing inventories and to maximize revenues through rising volumes. As a consequence, the Goldman Sachs and Citi camp lowered their WTI forecast for 2017 and 2018 further to $55/bbl for both years, and $57/bbl and $61/bbl respectively.

2017

The optimistic mood created after the ROPEC decision to cut oil production led to unprecedented long net speculative positions in the futures market in January 2017. Hedge funds and other money managers had accumulated a record net long position in the main Brent and WTI futures and options contracts equivalent to 885 million barrels by January 31. Stock markets had also rallied in November and December 2016 on the back of the election of Donald Trump as the new president, and the general view that the U.S. was now in an optimistic phase. Also a new type of fund was entering the oil markets. Beside the traditional investors, who are primarily focused on fundamentals and geopolitics, this time the length was also driven by large-scale macro funds, machine traders (having developed their own proprietary algorithm trading models) and momentum traders. This new breed of financial oil traders is more focused on macroeconomic and geo-finance factors and less on oil specific drivers, and thus is responsible for material inflows and outflows resulting in more short-term cycles in speculative length. Moreover, their behavior worked against more traditional trading schemes, having arguably put the funds trading the oil specific drivers on a wrong footing in 2017. That said, in the long run, market fundamentals of supply, demand and inventories are (arguably) likely to win over those who are trading primarily on macroeconomic themes and momentum.

In February 2017 funds had long positions equivalent to almost 1 billion barrels across the three major contracts while short positions amount to just 111 million barrels. The ratio of long-to-short positions reached almost 9:1, the most bullish since May 2014, when Islamic State fighters were racing across northern Iraq, and the Libyan civil war had halted crude exports. Analogous to August 2015, the crude market was starting to resemble the classic crowded trade in which speculators attempt to position themselves in the same direction in anticipation of a big price move. Fund managers apparently believed output reductions by ROPEC would succeed in draining excess global inventories rapidly, which would push oil prices higher. Managers were also discounting the threat from renewed drilling in the U.S. and a likely increase in output from shale producers, at least in the near term. But every successful trade needs an exit strategy and in this case it remained unclear how and at what price fund managers would manage down positions and try to take profits.

Due to stretched oil production by OPEC and non-OPEC countries in the last months of 2016, in anticipation of the cut, weekly inventories further increased well beyond their seasonal pattern in January and February, especially in the U.S. At the same time, prices rallied, a good example of the new interplay between the different types of investors described earlier. These higher imports were not the result of lower demand nor of higher domestic production, but due to increased imports. The surplus production in 4Q2016 was estimated at about 0.5 mb/d over demand. Moreover, optimistic guidance from U.S. E&P companies during the earning release period created worries over increased U.S. shale output. This was also given by strong hedging in the first months of the year when oil prices were (relatively) high, having secured their cash flows, and a large increase in mega projects coming on stream and ramping up in 2017-2019. By the end of the first quarter, producers had already added 346 oil rigs in the U.S., a 109% increase since its trough on May 27, 2016. However, with very high compliance by OPEC and participating non-OPEC countries, helped by cold weather in Russia, greater production cuts by Saudi Arabia, and further field production declines in Venezuela, it was expected that oil supplies to markets, especially to those West of Suez, would decrease as of March. Only a higher supply from Nigeria and Libya could spoil the party. All together the consensus WTI price outlook was surprisingly increased for 2Q2017 in late February. Instead, and not illogical, the oil price for WTI went down from $54.58/bbl on February 23 in three cycles to a new low on June 21 of $42.48/bbl. The main driver behind this price fall was caused by stubbornly high inventories around the world with June levels still materially higher than in January, irrespective of high compliance by OPEC and participating non-OPEC producers to their agreement. As a consequence, there was no alternative but for them to roll over their agreement to cut production, which they did at their May 25 meeting. In hindsight, the U.S. equity market had taken a pause in the first five months of the year, and thus did not deliver strong momentum either. Going forward, inventories needed sustained cuts to normalize and generate backwardation of the futures curve. Meanwhile, more investors in the energy space were increasingly throwing their towels in the ring in May. Clearly, oil bulls were nearing capitulation. Once inventories normalized, the view was that low cost producers would ramp up quickly again. With growing evidence of the ability of U.S. shale to lower their break-even costs at the well even further, the upside was increasingly seen as capped with WTI flat prices of $55/bbl for years to come. However, what was not clearly recognized was the return of reflation, in combination with an unexpected and rapidly weakening of the U.S. dollar from 1.05 to the euro at the start of the year to 1.14 on July 3 to 1.20 on September 4, giving a strong signal that oil prices should rise. These were the ingredients that the new breed of financial oil traders was looking for.

Finally, during the summer when prices hit their trough, ongoing inventory draws gave rise to an improved outlook. This was not only as a result of ROPEC living up to their promise, but perhaps even more due to very strong demand growth of 1.7 mb/d for the year. While the U.S. stock market was already in the optimistic phase - the final part of the cycle - since the election of President Trump, Europe was also on the brink of shifting to this phase. The bull market was finally in full swing. Some even started to point to a possibility that inventories should not fall too low in a too short period, as that would take prices towards $65/bbl, making the extended ROPEC cuts self-defeating. As things were moving forward into the 2nd half of the year, it became increasingly more likely that the oil market would finally enter the last phase of the cycle that had started in the summer of 2014 with the futures forward curve shifting into backwardation (which actually happened for Brent in the 3rd week of September), a signal of the normalization of the oil market. This would reflect a market that recognized near-term physical tightness while at the same time the lower forward price further out curtailed the market's ability to grow future production through forward sales. This thus means that fear of long-term surpluses could reinforce near-term shortages. The sharp increase in oil prices in November, which was pushed by robust oil fundamentals followed by the return of geopolitical risks in the Middle East, Nigeria and Venezuela ($57.34/bbl WTI, a new high for the year), raised the question of what to expect for the coming years.

2018

December 2017 and January 2018 were extremely good months for oil prices. Strong and simultaneous global economic growth, higher oil demand against limited supply growth due to ROPEC curtailments and a further weakening of the U.S. dollar to a recent euro-dollar rate of 1.25 on January 29 and rising inflationary concerns were the key drivers behind the rally. On the back of a new all-time high in net speculative length - money managers and hedge funds amassed a record net long position in Brent futures and option contracts equivalent to 600 million barrels and in WTI to 500 million barrels - Brent reached a new peak of $70 a barrel and WTI just over $66 a barrel in late January. Meanwhile, in January, the U.S. Energy Information Administration (EIA) announced that U.S. crude oil production had passed the 10 million barrels a day mark, just 6,000 bpd below the record set in November 1970. Basically, U.S. shale and prolific deep water developments in the U.S. Gulf of Mexico helped the United States to double production over the last ten years with a remarkable growth in crude oil of 850,000 barrels a day in just three months to November 2017. From an output perspective, the U.S. shale sector has fully recovered from the price and output slump that started in 2014. The wildcat nature of the early days of shale was unsustainable, but has now passed. But good rocks are good rocks and through forced discipline, efficiency gains, reduced costs and improved recovery, U.S. production has proved itself to be resilient and is poised to grow materially in the coming years. Consolidation is still lagging compared to the other segments in the oil sector, but that might eventually come in due course. Late January, ROPEC's Joint Ministerial Monitoring Committee also made it clear that at this point in time the agreement is more about oil price and near-term revenues than reducing inventories to their five-year average, which have been realized or are close to this depending on the way this is calculated.

Of course, the focus will soon shift to the principal risk that U.S. shale drilling will accelerate too fast, compliance in ROPEC will decline, production from non-OPEC non-shale sources will increase, and demand will decelerate owing to rising prices. Geo-finance elements are also starting to play a bigger role, as markets are entering a new era of volatility as the world adjusts to higher interest rates after a decade of ultra-loose monetary policy. But for the time being, none of these risks, with the exception of higher (but still modest) interest rates, appear likely to materialize imminently although the latest forecasts predict that U.S. Lower-48 onshore crude oil will grow by 1 million bpd in 2018 and only slightly less in 2019 with corresponding NGL production growth of 0.44 and 0.39 million bpd respectively. However, investors in shale are now much more focused on returns than on growth, and punish companies by pushing stock prices lower for those shale producers who do not give enough attention to dividend payments and buy-backs. In addition, OPEC and non-OPEC ex U.S. Lower-48 could add another 900,000 and over 1.1 million barrels a day in 2018 and 2019 respectively, pending the exact exit route of ROPEC. For the time being, they have communicated maintaining production restraint until the end of this year. Most shale producers have been in an excellent position to hedge their 2018 drilling campaigns in the last couple of months in case of a temporary fall in prices if too much new OPEC and non-OPEC supply comes on the market simultaneously. Given that we are now entering a new macroeconomic environment, oil price forecasts for 2018 and 2019 vary in a big way again. Where, for instance, Barclays and Citi had a \$66 and \$65 a barrel outlook for 1Q2018 respectively and no higher quarterly average prices this year and next year, Goldman Sachs raised its 3-, 6- and 12-month Brent oil price forecast to \$75.0, \$82.5 and \$75.0/bbl, resulting in an annual average price for Brent of \$77.5/bbl for 2018 while having raised the price for 2019 and 2020 to \$70 and \$60/bbl respectively. J.P. Morgan sees an average quarterly price of \$70, \$75, \$70 and \$65/bbl this year. And finally, Bernstein sees the oil price softening over the first half of 2018 to an average of \$55/bbl in 2018, basically not much different than the actual average price of 2017. They also see a gradual increase of \$60 and \$65/bbl in 2019 and 2020 respectively. The higher price outlook by Goldman Sachs is given by the expectation of (a) reflation where higher oil prices are driving inflationary pressure back up across the board, (b) releveraging in emerging markets (EM) due to strengthening balance sheets and strengthening EM FX (vs. the U.S. dollar), (c) reconvergence where EM growth catches up with developed market (DM) growth, and (d) each of these three factors reinforcing each other. In addition, capacity constraints in the midstream sector and timely availability of first-tier fracking crews could temper future production growth.

The consensus thus shows a higher oil price this year than in 2019. This is predominantly based on a view that markets will not further tighten because of ample supply from U.S. shale, ongoing production growth in non-OPEC countries from new fields coming on stream and others still ramping up, and the gradual return of ROPEC volumes currently constrained by the production curtailment agreement. On the demand side, growth may slow down, especially as the U.S. might shift into a recession. But oil fundamentals for 2018-2019 do not indicate any reasons to panic because of an emerging supply gap.

Field-by-Field Production Analysis through 2025

Having conducted a full field-by-field production study for 72 oil producing countries around the world for the period 1995-2025 in the fourth quarter of 2017, we see world oil liquids production peaking in 2020 under a rather conservative demand growth scenario if no new final investment decisions (FIDs) ex U.S. Lower-48 are taken as of today. This analysis included (a) all known sanctioned projects currently still ramping up or under construction, (b) known brownfield developments, (c) normal ongoing investments in producing fields, and (d) ongoing growth in tight oil as per EIA scenarios for the U.S. Lower-48. However, in the years thereafter, a supply-demand gap starts growing rapidly in the order of either 9.5 mb/d or 11.5 mb/d in 2025 under two different EIA scenarios.

In other words, during the rest of this decade, there seems to be no reason to be concerned about any shortfall. However, for the first half of the next decade, the big question arises if "Cheap Oil" and

"Medium Priced Oil" can close the gap beyond the projects included in our analysis. That is, can shale oil grow technologically and operationally faster than what has been projected in the EIA's scenarios, together with more new oil developments from countries such as Saudi Arabia, Iran and Iraq? (We included all Libyan oil currently offline due to the civil war as coming back on stream by 2020.) Will shale oil continue to be the swing producer that sets the overall price of oil, as covered in Till and Jesse (2016)? Or will the world be faced with a structural shortage in supply, which would trigger fast rising oil prices that would stimulate upstream investments in the "Most Expensive Oil" projects? In such a situation we basically return to the 1999 ($10 Oil World) through 2004 - 2006 period, when differently from foreseen, the oil market rapidly ended the "Demand-Led Oil World" of the 1990s and entered the "Supply-Constrained Oil World" of the 2000s. And thus that we could face another and most likely final "Supply-Constrained Oil World" before entering into an "Oil-Substitution World" in the 2030s.

Additional analysis shows that on the basis of annual field declines of -2 percent for OPEC countries and -5 percent for the non-OPEC ex U.S. Lower-48, the gap would be twice as big, approximately 22 mb/d by 2025. This means that already some 12 mb/d will be delivered by brownfield developments (about 5 mb/d) and sanctioned greenfield developments currently still under construction (7 mb/d). Another interesting result from the study was that U.S. shale production growth plus brownfield production growth from all other countries from 2011 onwards was so strong in the following years that it is only by 2020 that the production from these fields would fall below the level these fields were producing in aggregate in 2011. In other words, U.S. shale and brownfield developments (i.e., more production from legacy fields that were already producing before 2011) from Saudi Arabia, Iraq, Canada, Kuwait, the UAE, Russia and Brazil delivered about 11.2 mb/d, having compensated for a material field decline in most of the other countries. This raises the question if and when these major producing countries could do this another time in the years ahead and can thus fill a major part of the supply gap. Our analysis shows that over the period 1995 – 2025, the Top-15 producers add 35.2 million b/d while the bottom 15 producers lose -12.3 million b/d and the remaining 42 producing countries lose -2 million b/d. Over 5-year intervals, the aggregate volume added by the first 10 of the Top-15 producers has changed and will change materially: these countries added for instance 3 mb/d between 1996 and 2000, 5.8 mb/d between 2001 and 2005, 2.8 mb/d between 2006 and 2010, and 11.9 mb/d between 2011 and 2015. The Top-10 producers are expected to add 8.8 mb/d between 2016 and 2020 and only 0.9 mb/d between 2021 and 2025 if no new fields or big brownfields developments are sanctioned. This pattern can also be seen from the decline in new greenfield developments sanctioned during the latter intervals: Ex US-Lower-48, 310 large greenfield projects were developed around the world between 2011 and 2016. In late 2017, the number of sanctioned greenfield developments stood at 190 projects, many of which will be bringing less new oil supplies. Finally, out of the 72 producing countries, 20 show positive growth between 2010 and 2018. However, for the period 2018 – 2025, this number will decline to 9 if no new major projects are sanctioned.

Looking to the individual non-OPEC greenfield developments, historically around 9 to 10 new fields with production of more than 40,000 b/d came on stream a year with an average production of 134,000 b/d. However, as of 2019, this number falls on average to 3 per year, also with lower average production.

The big question now is whether the industry is prepared to increase activity in the upstream segment of the oil industry in the near future so that a gap will not materialize post-2020. Clearly, post-2020, shale alone can't do it. It needs material help from many other players. However, the Western oil companies are currently working on different priorities. There has been pressure to shift their portfolios to much cleaner fuels. Secondly, most Western oil companies have dramatically lowered their expected oil price to below $50 a barrel for planning purposes, and will stick to that figure irrespective of an oil price of $50 a barrel or $100 a barrel. Thirdly, these companies are still working on improving their balance sheets and their return on capital. Growing the oil upstream business, which have all-time low reserve – production replacement ratios, is not (yet) on top of their mind. Fourthly, outside the U.S., many companies left several upstream segments all together, having fired many engineers and project managers. In this respect, a world of "More Upstream / Profitable Downstream" as was the mantra in the early 2000s when the oil market entered an "Oil Supply-Constrained World" is not likely to come back, whatever oil price we face. Figuratively, these big oil tankers can't be turned overnight back to an old-fashioned business model. Today they are squarely working on transforming their companies for a new world post-2030. Fifthly, with respect to financing, the major banks lending to the oil industry find it increasingly difficult to stay committed to the industry because of reputation risks, higher capital costs due to Basel IV, and the possibility of ending up with stranded assets if the energy transition accelerates and leads to peak oil demand by 2030. Reduced access to capital might become a bigger issue and will be positive for commodity carry, reinforcing tightness at that time. Finally, from a geopolitical point of view, the Middle East, the other OPEC countries, Russia, Canadian oil sands, or Arctic are currently not seen as favorable hotspots for making large upstream investments. The question is whether the local players can do it themselves technically and financially.

Of course, new projects will be sanctioned and history shows that the gap will ultimately be filled. In particular, productivity gains, lower tax rates and project redesign will continue to drive engineering cost deflation. However, this time, also taking into account that a major oil development easily takes 5 years to build, it seems to become increasingly challenging to fill the gap completely and to do so with projects that have break-even costs of say $50 a barrel or less. If so, and no "Most Expensive Projects" are needed, we could then expect a smooth energy transition into an "Oil Substitution World" by 2030. However, if not enough projects are sanctioned in the next couple of years, there is no alternative than demand destruction through (much) higher oil prices to balance future oil supply and demand. Such higher oil prices could ultimately force central banks to raise interest rates to fight inflation. It could also result in a much lower U.S. dollar. In turn this could start hitting credits where companies cannot rely on ultra-cheap money as they have done in the last couple of years. Financing would become more expensive at a time when many loans have to be refinanced. Finally, by then, one could expect ROPEC to produce flat out. Under this scenario, once the current volumes that have been closed in come back on the market, not much spare capacity will be left until a new recession has set in and demand has come down materially. Ultimately, the fear for this to happen longer term would normally lead to a pick-up in new project sanctions.

Without doubt, the big winners in a higher-than-expected oil price world will be the big producers. U.S. shale producers and their service industry will do well. Only cost inflation could spoil the party to a certain extent. OPEC countries will do well too. Perhaps they will see this as their last and final opportunity to be quite profitable from their resource base before becoming a price taker in an "Oil Substitution World." Quite speculatively, the biggest winner could be Russia. Russia has not been hit by a depreciating dollar, and it already is well positioned to further build on its core strength to become a major influencer of world oil markets economically as well as politically. One could expect that Russia will make maximum use of its competitive advantage. Assuming a bigger role for itself versus OPEC countries, not only geopolitically, but also financially and economically, its ROPEC relationship could well be a crucial element in Russia's overall oil policy, enabling it to enforce power throughout the industry and to set the rules as a market maker.

Finally, it is plausible to assume that all incremental liquids production in the U.S. will leave the U.S., whether it is in light sweet crude, oil products or NGLs, as U.S refiners need imported sour crudes to run efficiently. Exports will thus rise rapidly from the U.S. Gross total exports already stood at 7 million b/d by the end of 2017. This figure is expected to increase. The U.S. is thus rapidly becoming a major oil hub. But this will not end in a physical hub alone. As described earlier, the way oil price discovery and price formation is changing with the arrival of new financially and macro-driven hedge funds, one could assume that this new model will also be exported to the rest of the world similarly to what is already happening in LNG, and will become a dominant influencer of oil prices. That said, Trade Wars in oil are very well possible, where the trend of liberalizing markets and reducing subsidies will stop and eventually reverse.

Conclusion

Clearly, the role of oil has not yet come to an end. So far demand has only grown this decade, the last years at an accelerated pace. The 100 million b/d demand mark will be achieved before 2020. It continues to be a spot asset class with little expectation value. The United States and Russia have definitely caught up and are now at par with Saudi Arabia. How they will work together and form bonds – especially between Saudi and Russia – will further determine the new rules of the game. The ever changing participants in the futures markets will also help in determining the new rules of the game as well. Whether the U.S. will continue to play the swing producer post-2020 is a big question. But it will definitely produce as much as it can to help avoid a growing supply/demand gap. In conclusion, assuming oil prices will never spike again is a rather risky assumption.

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Author Biography

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Mr. Jan-Hein Jesse has been active in the oil and gas industry since 1980. Mr. Jesse is also an independent director and advisor of Centerbridge Partners (U.S.A., U.K.) and AT Capital (Singapore). He is the former head of Energy Finance at ING Bank, a former senior manager Mergers & Acquisitions at Shell, and the former CFO of Heerema Marine Contractors. He is an expert for the International Energy Agency, a visiting fellow of Clingendael International Energy Programme (CIEP, The Netherlands), and is a member of the Chief Economic Roundtable Group at the Ministry of Economic Affairs of The Netherlands. He lives in Amsterdam.

Positioning Analysis in Commodity Markets: Bridging Fundamental and Technical Analysis

Mark Keenan
Managing Director, Global Commodities Strategist and Head of Research for Asia Pacific, Société Générale Corporate & Investment Bank (Singapore); and Editorial Advisory Board Member, *Global Commodities Applied Research Digest*

Mr. Mark Keenan, Managing Director, Global Commodities Strategist and Head of Research for Asia Pacific, Société Générale Corporate & Investment Bank (Singapore), presenting on the energy markets at the EnergyRisk Asia 2017 conference in Singapore on November 22, 2017. Mr. Keenan joined the *GCARD*'s Editorial Advisory Board in the spring of 2018.

Published in January 2018, the book, Positioning Analysis in Commodity Markets, defines and establishes "Positioning Analysis" as an area of research that provides a powerful framework to better understand price dynamics, risk, sentiment and behavior in commodity markets.

Based on standard positioning data and bridging aspects of fundamental and technical analysis, the approach builds on how certain types of positioning patterns, in the context of changes in variables like price, curve structure, fundamentals such as inventory, seasonal factors, exchange rates, changes in the broader macroeconomic environment and the levels of risk and uncertainty in the market, can be used to develop models, indicators and analyses. These lead to the generation of robust trading signals that can be used directly, or can be integrated into a variety of different trading, investment and risk management programs to enhance performance.

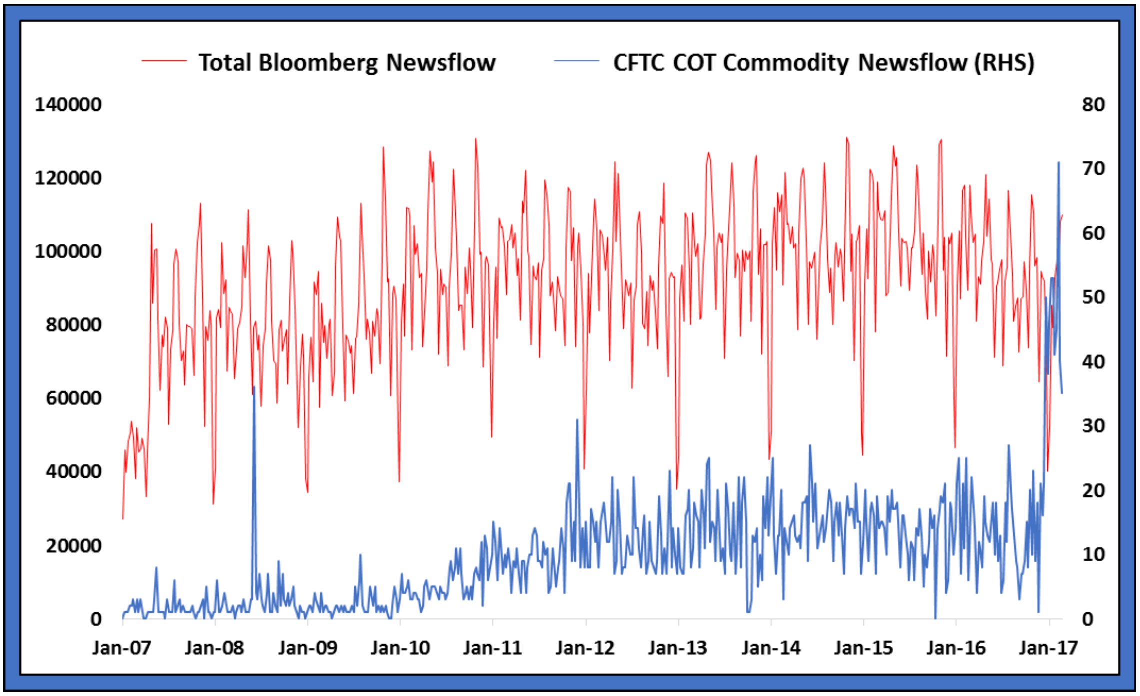
Positioning data shows us who is trading what, and how much they are trading; Positioning Analysis shows us what can happen when they trade too much, and how changes in specific variables affect positioning and impact price.

Overview of the Book

Positioning Analysis is a vast area with a wide range of applications in trading, investment and risk management. The jump in positioning related newsflow in Figure 1 on the next page shows that interest in positioning has also been increasing significantly. This is important as there is often a strong component of self-reinforcement to positioning dynamics in commodity markets.

The book, Positioning Analysis in Commodity Markets (2018), has over 300 images explaining a wide range of models, indicators and analyses across more than 25 different commodity markets. In many cases, their construction is unique, but in all cases, the approach is robust, intuitive and accessible to market participants and risk managers on a variety of levels. The objective of this article is to highlight some of the main areas in the book, chapter-by-chapter, and provide some insight into Positioning Analysis.

Figure 1
A Steep Jump in Positioning Related Newsflow Since Early 2017 (Blue);
This Compares to the Unchanged Profile for Total Newsflow (Red)



Data Source: The Bloomberg.
Note: Positioning newsflow index built by Mark Keenan.
Abbreviations: CFTC stands for the Commodity Futures Trading Commission; and COT stands for the Commitments of Traders report.

Positioning in Commodity Markets

Positioning data often invokes strong opinions about its validity and usefulness - and is therefore not unlike technical analysis in this respect. In Chapter 1, many of the more widespread concerns, such as the "lag" in the data, the "age" of positions, how certain types of traders are classified and how specific types of trading is interpreted are addressed.

Most of the analysis, indicators and models discussed in the book can be applied to different trader categories, which as explained throughout the book, is important in helping to formulate a more complete picture of the overall positioning landscape in a commodity. The chapter also spends some time in explaining the motivation behind each trader, which is helpful in understanding how price, curve structure and sentiment can evolve under different circumstances.

The Structure of Positioning Data: the Commitments of Traders (COT) Reports

Understanding the structure of positioning data, specifically regarding the classifications and how the data is reported, is a prerequisite to understanding Positioning Analysis. The extent and complexity of the relationships, patterns and dynamics between changes in open interest and changes in the number of traders both within, and between trader categories are considerable. Chapter 2 gives a clear overview of how positioning is attributed between categories.

The chapter also shows how COT data can be used to understand and evaluate positioning patterns and profiles between the major commodities. The analyses show which commodities are the most liquid, which have the highest number of traders in each category, which are the most (and least) speculatively driven, which have the highest degree of spread related activity and in which commodities traders hold the largest positions. Collectively, this information provides a solid foundation for many of the models and analytics presented in later chapters. This chapter also gives general insights into which commodities might be the most vulnerable to shifts in sentiment and from an investment perspective, based on the positioning patterns and profiles in each commodity, whether technical strategies or more fundamentally driven approaches might perform better.

Positioning and Skill: Where Do Speculators Generate the Best Returns?

Information on the skill of speculators, specifically where they generate returns, is important in deciding whether speculative positioning data should indeed be analyzed and used as an indicator to help understand market direction.

Chapter 3 evaluates the performance of Money Managers (MMs) in individual commodity markets using a robust and intuitive analytical framework. Two distinct aspects of speculative positioning are considered – net futures positioning and positioning based on the net number of traders. Combining the results from both these analyses provides valuable insights into performance and helps answer questions on whether speculators have been more skillful in generating absolute or relative returns, which commodities they are best at trading, and whether positive returns are generated by a few large traders in each commodity, or more widely across all traders.

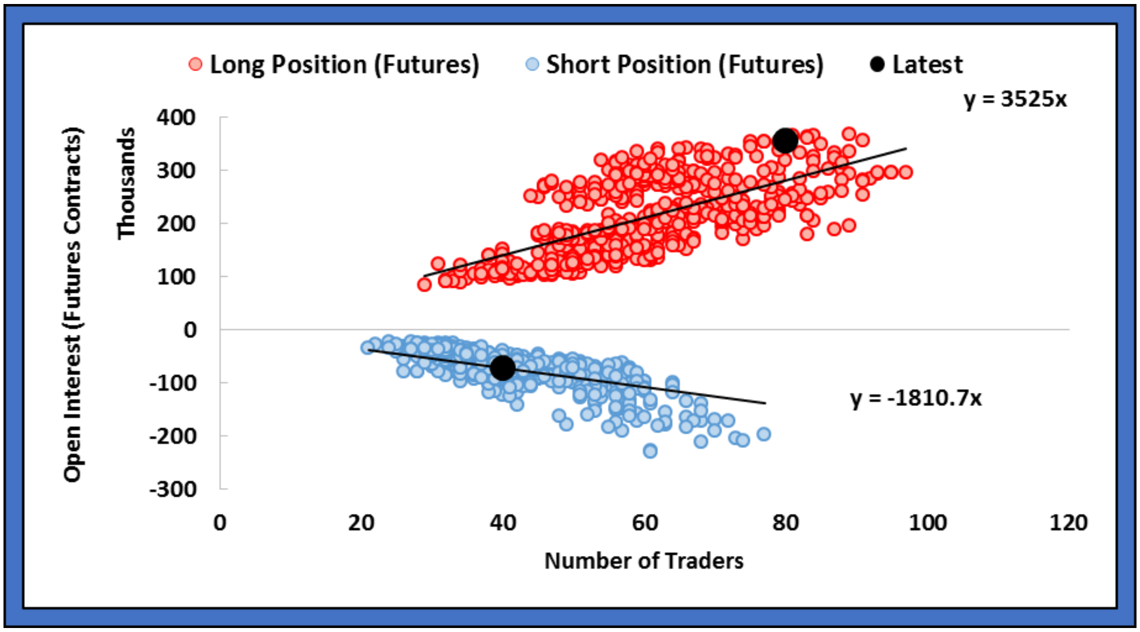
"Dry Powder (DP)" Analysis: An Alternative Way to Visualize Positioning

Chapter 4 introduces Dry Powder (DP) Analysis as a powerful way of visualizing positioning in commodity markets. The analysis reconciles historical long and short open interest in a specific trader category, with the number of traders (trading entities) holding the position in that category.

The data is brought together in the form of DP charts, which is shown on Figure 2 on the next page. These can be directly used as trading indicators to help decide the likelihood of an existing position becoming bigger (how much dry powder is available), and of the position nearing an extreme and growing vulnerable to liquidation. Due to the dynamic nature of speculative positioning, DP charts for Money Managers (MMs) are particularly important in understanding price direction, identifying price risks and discovering trading opportunities.

DP charts can be modified in a variety of ways to isolate specific positioning dynamics and lend themselves well for use in conjunction with other indicators and models to refine trading signals and enhance risk management. Their application is widespread and useful across a wide variety of trading, hedging and investment mandates.

Figure 2
Dry Powder (DP) Analysis of the Money Manager (MM) Category for Crude Oil (WTI)



Data Source: The Bloomberg.
Data Range: June 13, 2006 through December 20, 2016.

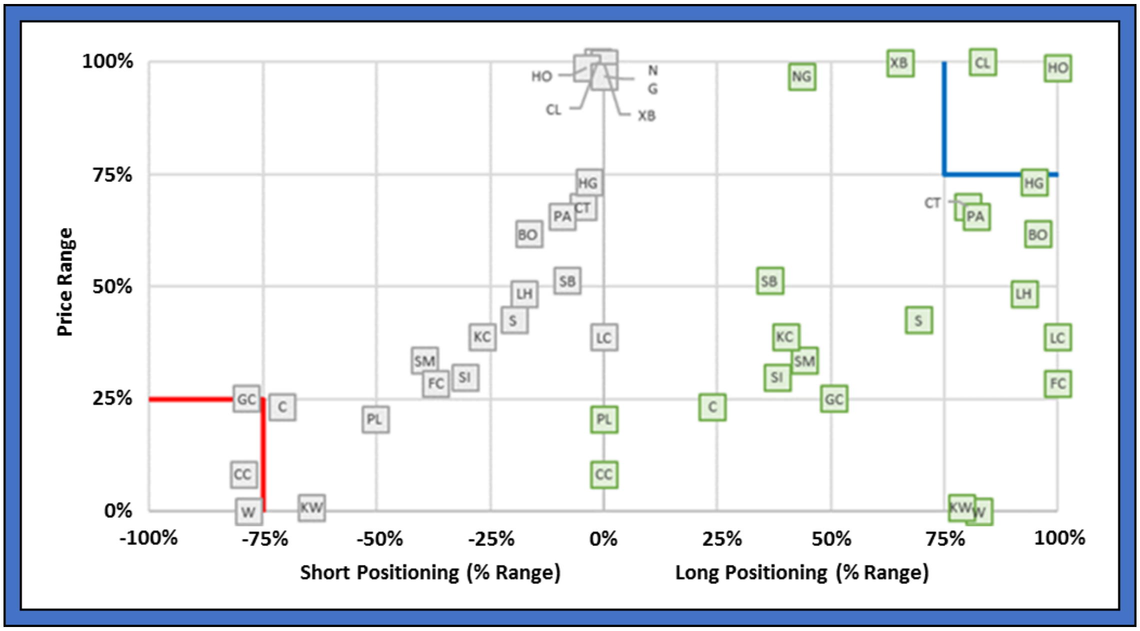
The OBOS Framework: The Intersection of Positioning and Price Extremes

Chapter 5 introduces the Overbought/Oversold (OBOS) framework and the OBOS Position indicator. The OBOS framework is used to evaluate and track behavioral patterns in commodities at the intersection of extremes in their long and short speculative positioning and extremes in their price. Speculative positioning extremes often give useful trading insights, but it is mostly in the context of price extremes, that they become particularly powerful.

The OBOS Position indicators are used to show behavioral patterns that occur at the intersection of extremes in positioning and price across a variety of different commodities. The indicators are derived from the OBOS framework and use combinations of speculative positioning data and pricing data, at specific thresholds, to define when commodities become "Overbought" and "Oversold," and to generate precise trading signals and reliable risk alerts.

For the OBOS Position indicator to be able to generate trading signals, Overbought and Oversold thresholds need to be formalized for each of the Positioning Components and the Pricing Component to define the extremes. The "default" thresholds for the OBOS Position indicator are the top and bottom quartiles (25%) of both the Price and the Positioning Components over specific ranges. These thresholds are indicated in Figure 3 as the blue (overbought) and red (oversold) boxes.

Figure 3
The OBOS Position Indicator Profile with Overbought (Blue) and Oversold (Red) Boxes

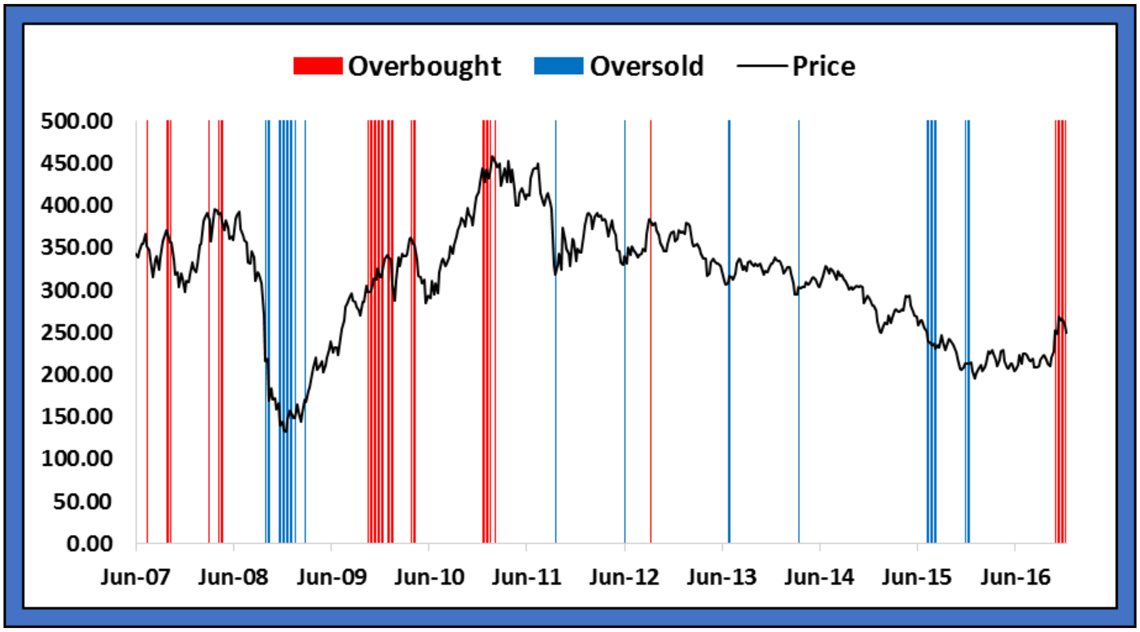


Data Source: The Bloomberg.
Data as of December 23, 2016.
Each box represents a commodity (Bloomberg symbols).
Short (long) positioning are shown in grey (green) for each commodity.

The OBOS framework is highly customizable. Figure 4 on the next page, for example, shows instances of overbought and oversold signals for COMEX copper at a 10% threshold with few signals. The blue (red) bands show how many of the signals coincide well with future moves higher (lower) in price.

In Chapter 6, the Hybrid DP/OBOS framework, as a means of addressing a fundamental weakness in DP Analysis – the subjectivity of trading signals; and also a weakness in the OBOS framework – the risk that the price of an Overbought (Oversold) commodity can continue rising (falling), is introduced. This allows for more precise trading signals to be generated.

Figure 4
OBOS Position Indicator Signal Chart for COMEX Copper with the Thresholds Tightened to Deciles (Top and Bottom 10%)



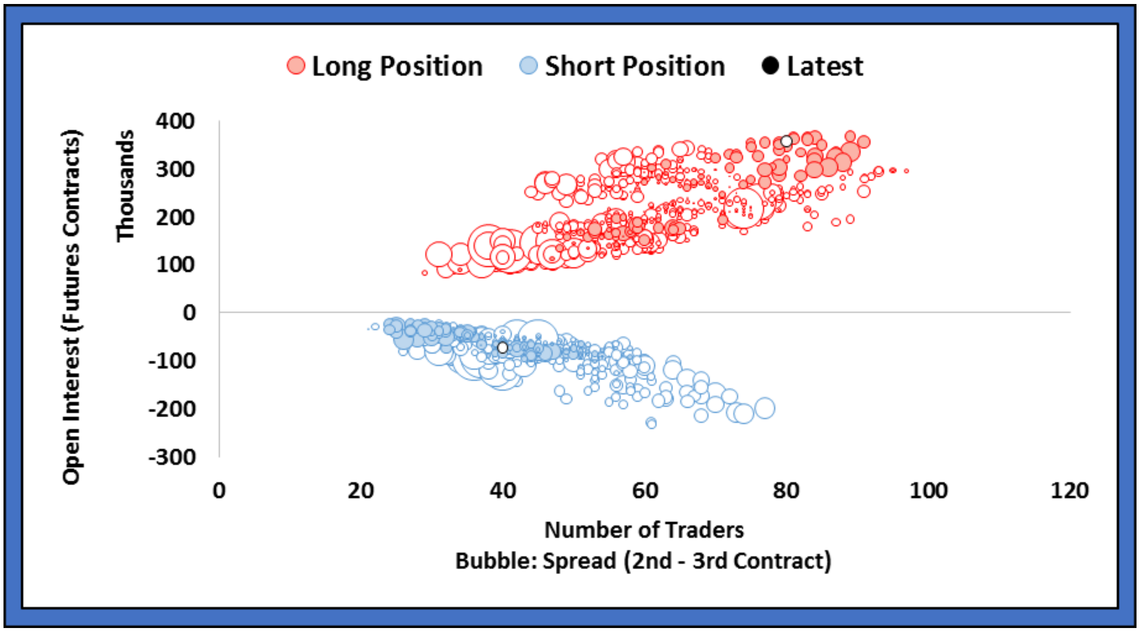
Data Source: The Bloomberg.
Data as of December 23, 2016.

Dry Powder Bubbles (DPB): Deeper Insights and More Variables

Dry Powder Bubbles (DPB) are introduced in Chapter 7 as an intuitive way of incorporating more data and more varied types of data into DP analysis. These can include data on other trader categories, the price of the underlying commodity, the shape of the forward curve, fundamental data, or macroeconomic variables. This allows for new positioning patterns to be identified in the context of different variables.

Figures 5 on the next page, for example, shows the clear proclivity for money managers to build large long (short) positions only when the curve structure is in backwardation (contango) and favorable in terms of roll yield. Interestingly there have never been any meaningful short positions when the curve is backwardated.

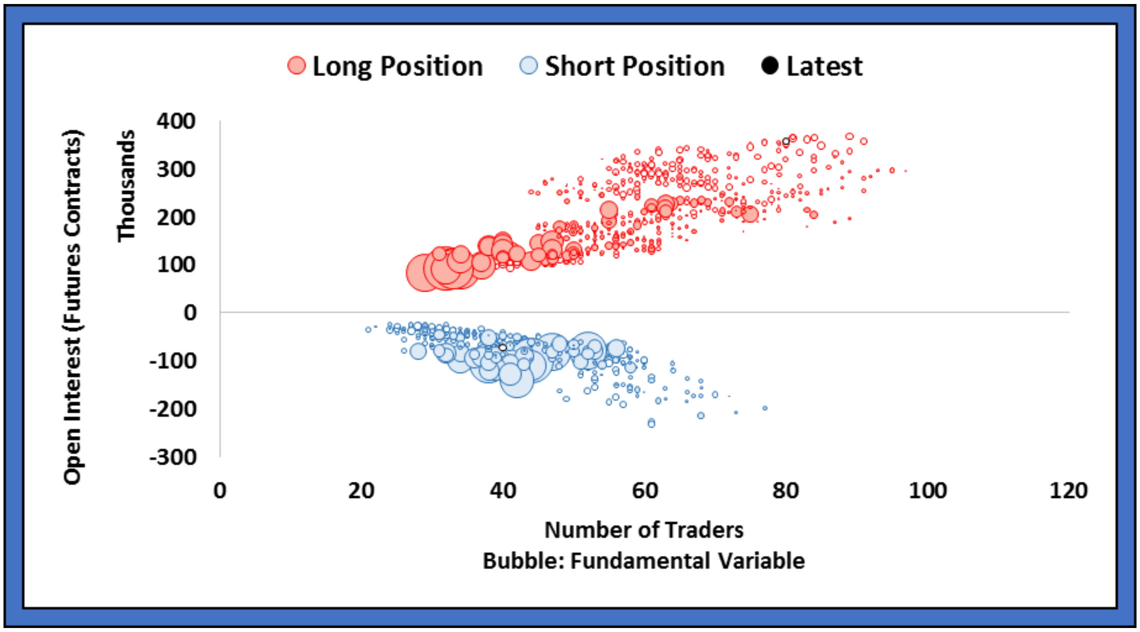
Figure 5
DP MM/Curve Bubbles for Gasoil
Shaded (Hollow) Bubbles Show Backwardation (Contango)
Large Bubbles Indicate Wider Spreads – Greater Backwardation or Contango



Data Source: The Bloomberg.
Data as of December 23, 2016.

Figure 6 on the next page shows the pattern between speculative positioning in WTI and the level of the VIX index. Here large speculative long positions rarely occur when the VIX is elevated.

Figure 6
DP MM/Macro Bubbles for Crude Oil (WTI)
Large Shaded (Hollow) Bubbles Indicate More Positive (Negative) Z-Score of the Level of VIX



Data Source: The Bloomberg.
Data as of December 23, 2016.
Curve structures measured between the 2nd and 3rd nearby contracts.

Concentration, Clustering, and Position Size: Price Risks and Behavioral Patterns

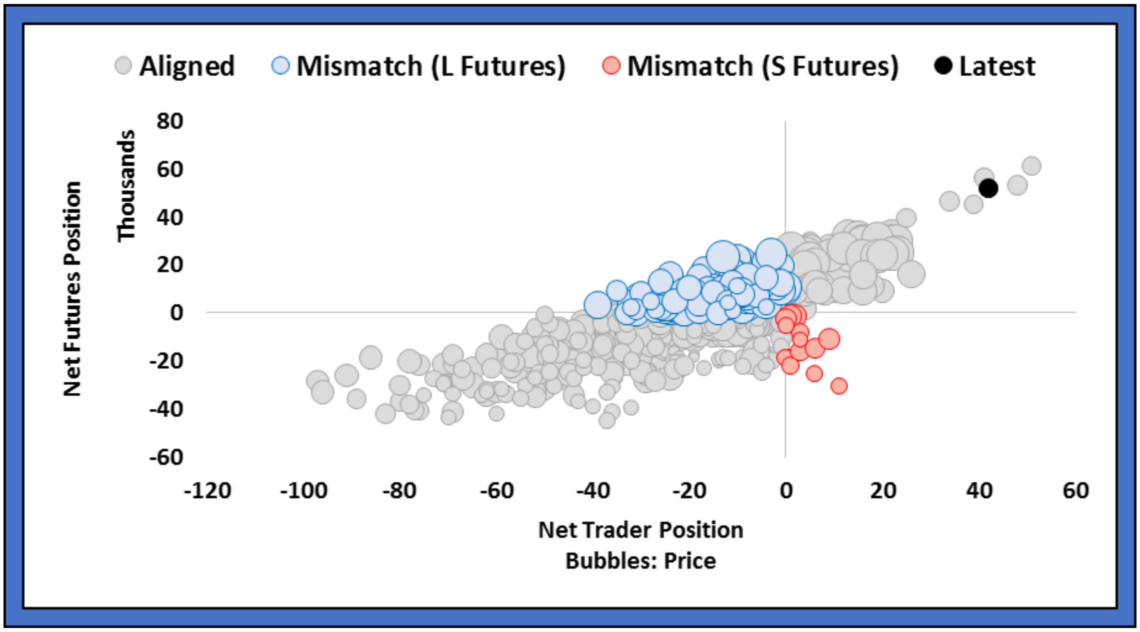
Chater 8 looks at different ways of implying the size of positions on an individual basis. Specific Concentration, Clustering and Position Size metrics offer insights into aspects of the level of conviction in the market, the strength of sentiment as well as providing a way of measuring positioning risk and any inadvertent risk clustering.

Sentiment Indices and Positioning Mismatches: Tracking Sentiment Dynamics

Changes in the number of individual traders holding a long, short, or spreading position, as opposed to changes in the open interest of their aggregate long, short, or net positions offers considerable insight into the collective thinking and sentiment in a trader category. These changes, either in isolation, or in combination, with changes in open interest, can be used to understand shifts in sentiment, to enhance trading models and to generate powerful trading signals. Two different types of Trader Sentiment Indices (TS Indices) are developed in Chapter 9: Directional Sentiment (DS) indices are based on the number of long and short traders only; and, Non-Directional Sentiment (NDS) indices are based on the number of traders holding a spreading position.

The concept of a positioning Mismatch is explained. Mismatches occur between the net number of individual speculative traders (number of long traders – number of short traders) and their net speculative futures position (long speculative open interest – short speculative open interest). When the direction in the net number of traders is different to the direction of the net futures position, these data are considered to be misaligned, and a Mismatch is defined. Mismatches can lead to powerful trading signals, as mismatches often intersect with price inflexion points. Figure 7 shows a Mismatch chart for copper.

Figure 7
Mismatch Chart for Copper



Data Source: Bloomberg.
Data Range: June 13, 2006 through December 20, 2016.

The OBOS Factor Framework: Extremes in Fundamental, Macro and Sentiment Factors

In Chapter 10 a series of OBOS Factor indicators are derived from the OBOS Factor framework. They are like OBOS Position indicators, except the Pricing Component is substituted for a Factor Component. These indicators aim to isolate periods of extreme speculative positioning and extremes in these factors to understand better how commodities behave in more macro-driven environments, to enhance existing trading signals and to generate new trading signals. The factors include variables such as the VIX, the VVIX, Financial Conditions Indices (FCIs), the dollar index (DXY) and certain commodity currencies.

The Seasonality of Positioning: Seasonal Patterns in Positioning

Chapter 11 looks at patterns in the seasonality of positioning. These can be used alongside many of the indicators and analyses in earlier chapters, to better understand positioning behavior and to refine trading signals.

In general, seasonal patterns in commodities exist in a variety of different channels and affect many aspects of commodity pricing. Changes in the shape of the forward curve and price are usually the most common effects, but seasonal dynamics can also drive shifts in sentiment, influence trading behavior, shape risk appetite and impact fundamental variables.

Blending it All Together: New Insights into Commodity Trading

The final chapter describes how different market participants could use the models, indicators and analyses in the book, either individually or in combination, to enhance their trading, investment, and risk management. For each of the major market participants, encompassing consumers, producers, merchants, speculators, and commodity index (including risk premia) investors, some of the most relevant positioning indicators are described in the form of a "checklist."

Author Biography

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Mark Keenan is the Global Commodities Strategist and Head of Research for Asia-Pacific (Managing Director) at Société Générale Corporate & Investment Bank in Singapore. He is also the author of Positioning Analysis in Commodity Markets (2018). With over 20 years of research, trading and investment experience across all the major energy, metal, agriculture and bulk commodity markets, Mr. Keenan works with corporates, trade houses, investment institutions and hedge funds to develop better trading, hedging and investment solutions. Specific expertise in modelling supply and demand data, combined with sentiment, uncertainty, flow and positioning analysis helps him understand commodity price behavior and how it responds to changes in currencies and a variety of different macroeconomic variables. Mr. Keenan has worked in asset management, risk management and investment banking in both London and Singapore. He appears regularly on CNBC and Bloomberg television and is quoted widely in global press and media channels. He has a B.A. and M.A. in Molecular and Cellular Biochemistry from Oxford University.

Volatility in Crude Oil Markets: Trading and Risk Management

Vito Turitto
Manager, Quantitative Analysis, S&P Global Platts (U.K.)

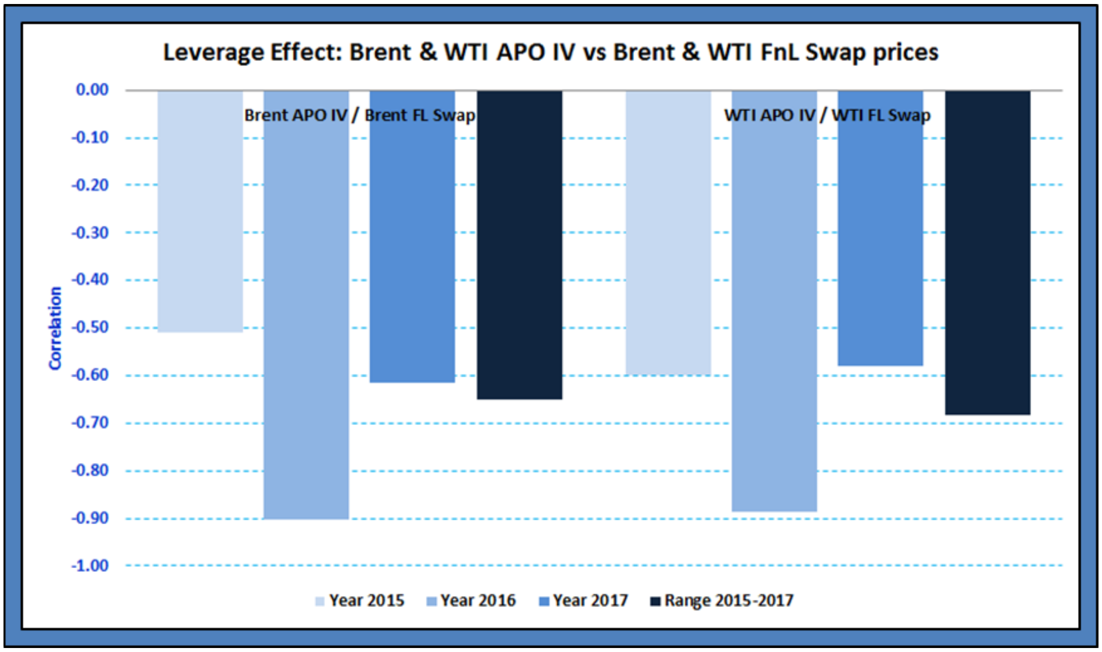
Volatility is the other name of market risk. Hedging against unwanted market fluctuations has always been one of the key topics in the commodities business, and in particular, within the energy industry. Crude oil producers, refiners, shipping and transportation companies are all concerned about how to limit their exposure to unwelcome price oscillations in order to lock into profitable refining margins, have steadier cash flows (and consequently higher P/E ratios), limit costs and have a more stable business model.

Whether market participants want to trade speculatively or they are interested in hedging their physical exposure, it does not really matter. All of them are affected by price volatility and they must manage it. Two key facts about volatility are as follows: 1) volatility is asymmetric, and 2) volatility is mean reverting.

Let's start by examining the first feature: asymmetric volatility. Asymmetry means that volatility will tend to behave in a certain way if the Brent or the West Texas Intermediate (WTI) market moves down, but it will behave in a different way should crude oil prices trend up. Clearly, the practical implications of such a relationship can be applied to both hedging and trading strategies and therefore it is important to quantify it.

As shown on Figure 1 on the next page, over the last two years the correlation between Brent Frontline (FL) swap prices and Brent implied volatility (IV), extracted from Brent average price option (APO) premiums, has clearly been negative. Specifically, it was negative 0.50 in 2015; it achieved negative 0.90 in 2016; and it was negative 0.61 in 2017 while it averaged negative 0.65 between 2015 and 2017. The same relationship was identified in the WTI Crude market (WTI Frontline swap prices vs WTI implied volatility extracted from WTI average price option premiums) where the correlation was minus 0.59 in 2015, negative 0.88 in 2016, and negative 0.58 in 2017 while it averaged negative 0.68 throughout the aforementioned two-year period. The negative link between implied volatility and swap prices is a consequence of the propensity of market participants to hedge against price retracements using options. The buying pressure on put options tends to lift the put skew rather quickly which, in turn, causes the implied volatility to increase.

Figure 1



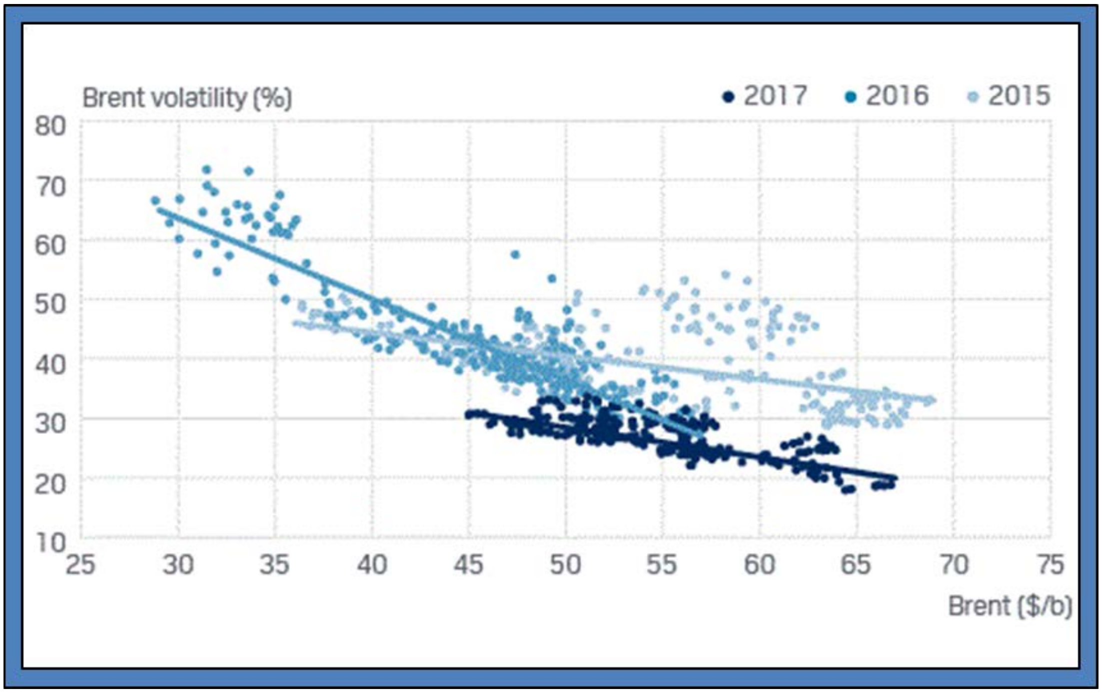
Source: S&P Global Platts Analytics.

Abbreviations: APO stands for Average Price Option; IV stands for implied volatility; and FnL and FL stand for Frontline.

Things are different when the market experiences an uptrend and prices tend to move up.

Figure 2's scatter plot on the next page shows rather clearly the leverage effect process between prices and implied volatility. When Brent prices, on the x axis, go down, the implied volatility, y axis, inevitably moves up. Conversely, a market uptrend is usually accompanied by a decreasing implied volatility. The regression lines visually show the perfectly linear relationship between prices and implied volatility. If there were a direct, rectilinear rapport between the two factors, all the observations would be neatly clustered and almost evenly dispersed around them. Consequently, the higher the divergence from the fit line is, the less efficient a hedging or trading strategy will tend to be. It is worth pointing out that in the oil business in particular, such sharp and short-lived divergences are by no means rare, due to geopolitical risk or crude supply shocks.

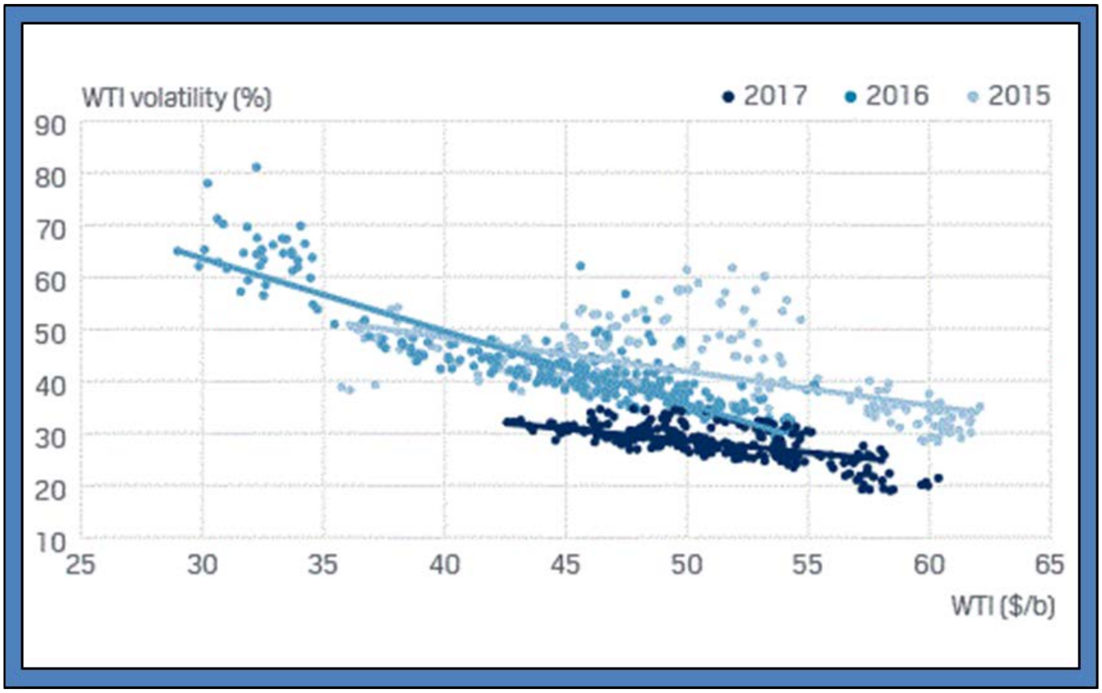
Figure 2
Brent Leverage Effect



Source: S&P Global Platts Analytics.

The same relationship is also identified in the American WTI crude market over the 2015-2017 period, as shown on Figure 3 on the next page.

Figure 3
WTI Leverage Effect



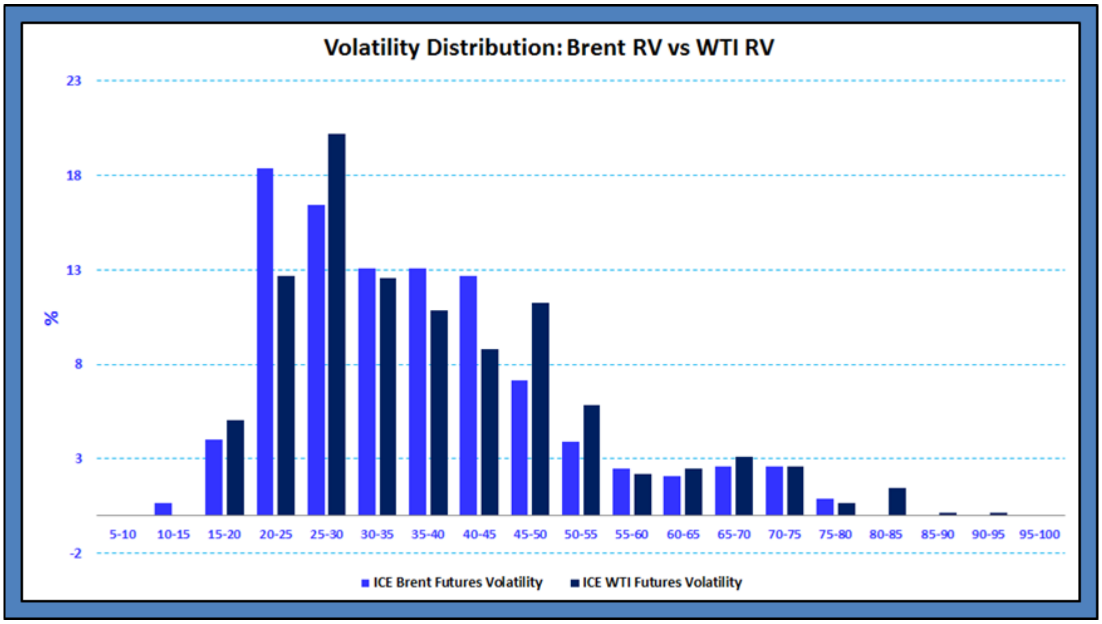
Source: S&P Global Platts Analytics.

It is important to point out that part of the reason why implied volatility moves inversely to prices is due to the speed with which the market trends. Crude oil prices tend to crash a lot more quickly than they uptrend, and this phenomenon has a clear impact on the fluctuation rate of the market. Furthermore, the higher speed with which the market downtrends incentivizes many speculators to place trades in order to realize quick profits with their behavior inevitably exacerbating the jump in volatility.

The second important feature of volatility is its propensity to mean reversion.

Figure 4 on the next page documents the distribution in realized volatility (RV) from 2015 through 2017 in Brent and WTI futures prices. Both Brent and WTI realized volatilities, on average, fluctuated between 20% and 30%. The mean-reversion propensity of volatility can be observed by the fact that the fluctuation rate for both crude grades was lower than 20% and higher than 50% less than 5% of the times. Furthermore, it is interesting to note that Brent and WTI volatilities fluctuate in a different way: WTI tends to be more volatile than Brent. Specifically, Brent's equilibrium level is within the 20%-25% range while WTI's is 25%-30%. Also, the probability of volatility trading above 45% is higher for WTI than it is for Brent, implying that the American crude market's fluctuation rate spikes more often than that of the European grade. The volatility distribution analysis can provide a map for crude oil market risk because it can help in identifying the turning points in the market.

Figure 4

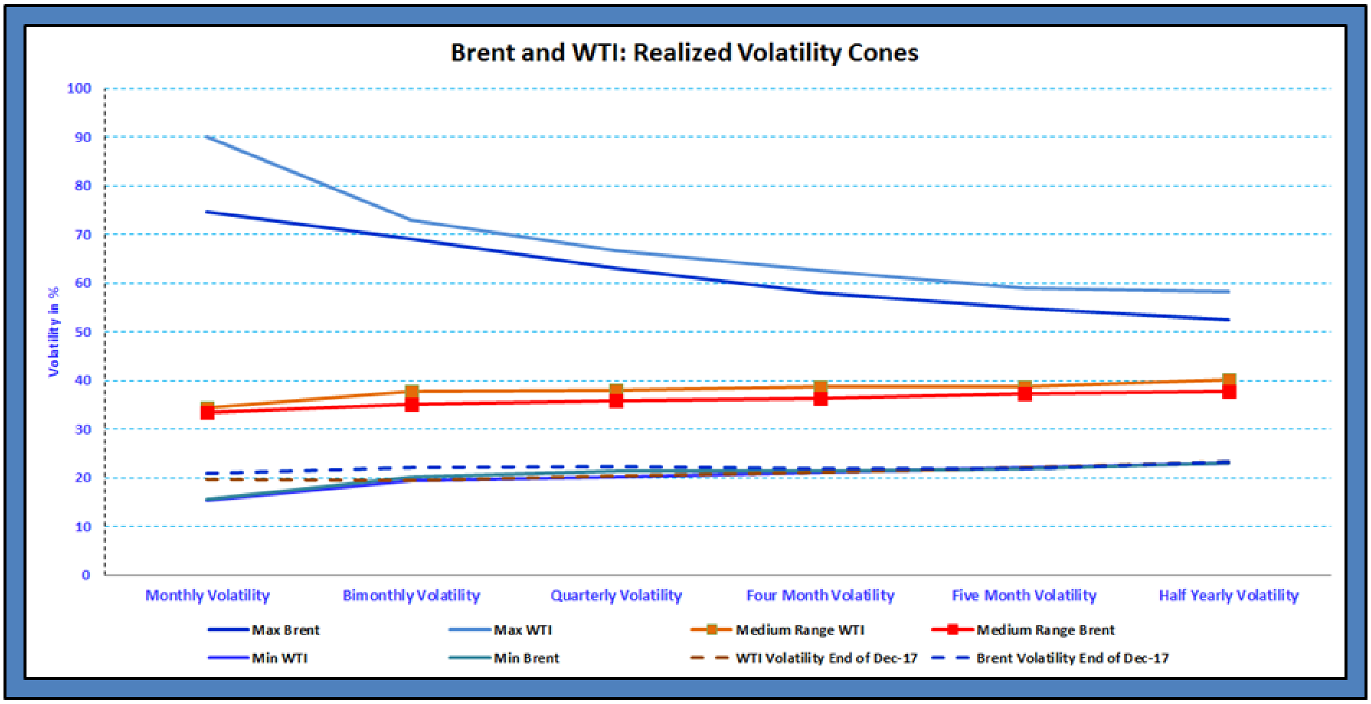


Source: S&P Global Platts Analytics.

Abbreviation: RV stands for realized volatility; and ICE stands for the Intercontinental Exchange.

A volatility cone analysis, such as in Figure 5 on the next page, is a valuable tool to historically contextualize the actual fluctuation rate. It effectively helps to understand whether current volatility is low or high compared to its distribution over a certain period of time (in this case from 2015 to 2017). The WTI and Brent volatility curves (dotted lines) that have been computed using prices as of December 2017 are seen to be near their lowest levels in two years, indicating at the time that options would be regarded as cheap.

Figure 5



Source: S&P Global Platts Analytics.

Concluding Remarks

The mean-reversion propensity of volatility and its asymmetric movement are important factors that market participants should use when designing hedges for their market exposure as well as to identify trading opportunities using options.

Endnotes

All examples in this report are hypothetical interpretations of situations and are used for explanation purposes only. The views in this report reflect solely those of the author and not necessarily those of S&P Global Platts or its affiliated institutions. This report and the information herein should not be considered investment advice or the results of actual market experience.

Author Biography

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Interview with Professor James Hamilton

Professor of Economics, University of California, San Diego; Co-Chair of the JPMCC's Research Council; and Distinguished Visiting Fellow at the JPMCC

Dr. James Hamilton, Ph.D., Professor of Economics, University of California, San Diego, presenting at the J.P. Morgan Center for Commodities' (JPMCC's) international commodities symposium, "New Directions in Commodity Research," which was held at the University of Colorado Denver Business School from August 10 through August 11, 2017.

In the Summer 2018 issue of the *GCARD*, we are honored to interview Dr. James Hamilton, Ph.D., Professor of Economics, University of California, San Diego. Professor Hamilton is also the Co-Chair of the JPMCC's Research Council in addition to serving as the JPMCC's Distinguished Visiting Fellow. In our interview, Professor Hamilton explains what originally spurred his interest in the impact of oil price increases on the economy, followed by what he currently sees as important research issues. He also touches upon what encouraged him to become involved with the JPMCC and its Research Council, noting some of his goals for the Research Council and its international commodity symposia. The interview concludes with Professor Hamilton discussing both the impact the JPMCC could have on the commodity industry and his recommendations for future topics in the *GCARD*.

Professor James Hamilton (right), Ph.D., University of California, San Diego, in discussion with Professor Lutz Kilian (left), Ph.D., University of Michigan, Ann Arbor, during the JPMCC's inaugural Research Council meeting at the University of Colorado Denver Business School on April 18, 2015. Both Professor Hamilton and Professor Kilian are members of the JPMCC's Research Council.

Interview with Professor Hamilton

Professor Hamilton, your research has had a significant impact around the world. For example, your advanced econometrics textbook, Time Series Analysis, is widely used by researchers in modeling the economy. In addition, your research has helped to guide U.S. monetary policy. What are your current research interests?

One of my goals is to get researchers to incorporate uncertainty about the underlying structure of the economy into statistical conclusions they draw from the data. The usual approach is to report standard errors that assume that none of the structural assumptions underlying the analysis are in doubt. I'm advocating a Bayesian approach in which uncertainty about those assumptions is incorporated into the statistical inference along with the usual sources of measurement error. I'm working on a couple of papers with Notre Dame Professor Christiane Baumeister showing how this can be done in estimating the contributions of supply and demand to historical oil price movements and in assessing the effects on the economy of monetary policy.

I also have ongoing projects on getting better measures of underlying trends, reconciling reporting errors in the unemployment statistics we rely on, and the effectiveness of the Federal Reserve's quantitative easing.

Your Ph.D. dissertation was on the impact of oil price increases on the economy. What originally spurred your interest in this topic, and what were the public policy consequences of your research insights?

I was taking a time-series course at UC Berkeley for which we were supposed to do an empirical project. I was astonished to find that big supply disruptions and attendant economic downturns were not just a phenomenon of the 1970's but were a recurrent feature of the data. And of course we've seen a number of episodes since then repeating the same pattern.

I think that research has helped government and private planners to anticipate better some of the economic problems that can arise in these episodes and to recognize the importance of reliable energy sources for economic growth. For example, that research may have been one factor in deciding to release stockpiled oil in 2005, which I think was beneficial. But it is easy to get complacent in environments like the present and forget just how turbulent events in the Middle East can become on short notice.

What are the most important research issues at present in studying the impact of oil price changes on the economy?

The recent oil price decline gave us some useful new data that has resulted in some interesting new research. With the large datasets we now have available it is possible to document what goes on at the micro level of individual consumers and firms. Some great new insights have already emerged from that, and I expect more in the future.

Thank you very much for agreeing to co-chair the J.P. Morgan Center for Commodities' (JPMCC's) Research Council and also for recently becoming the JPMCC's first Distinguished Visiting Fellow. What encouraged you to become involved with the JPMCC and its Research Council?

I grew up in Colorado, and was pleased to see this develop into a center for research. Given the abundance of resources in the Mountain West, this seems a natural place to house the center.

What are some of your goals for the Research Council and its international commodity symposia over time?

I think bringing academics and industry professionals together is a very important goal. Academics can get too specialized and tied up in unrealistic assumptions without input from practical business people. And there is a lot of expertise the academic community can bring to help practitioners to interpret trends and make better decisions.

What impact could the JPMCC have on the commodity industry?

In addition to benefitting both academics and practitioners, the training of new students with a solid training in modern methods and insights is a major asset to the industry.

What topics would you recommend that we cover in futures issues of the practitioner-focused GCARD?

I mentioned some of the insights coming from analysis of huge data sets. These include the analysis of consumer behavior by the JPMorgan Chase Institute and Michigan Professor Matt Shapiro and co-authors, and the analysis of oil drilling incentives and profitability by Chicago Professor Ryan Kellogg and co-authors and Norwegian Business School Professor Hilde Bjornland and co-authors.

Thank you, Dr. Hamilton, for this opportunity to interview you!

JAMES HAMILTON, Ph.D.
Professor of Economics, University of California, San Diego

Professor James Hamilton has published on a wide range of topics. His research in areas including econometrics, business cycles, monetary policy, and energy markets has been cited by more than 40,000 other studies. His graduate textbook on time series analysis has sold over 50,000 copies and has been translated into Chinese, Japanese, and Italian. He also contributes to Econbrowser, a popular economics blog. Academic honors include election as a Fellow of the Econometric Society and Research Associate with the National Bureau of Economic Research, receipt of the Best Paper Award for 2010-2011 from the International Institute of Forecasters, and the 2014 award for Outstanding Contributions to the Profession from the International Association for Energy Economics. He has been a visiting scholar at the Federal Reserve Board in Washington, DC, as well as the Federal Reserve Banks of Atlanta, Boston, New York, Richmond, and San Francisco. He has also been a consultant for the National Academy of Sciences, Commodity Futures Trading Commission and the European Central Bank and has testified before the United States Congress. Professor Hamilton received the UCSD Economics Department Graduate Teaching Award on five different occasions.

International Association For Quantitative Finance

About the IAQF, the *GCARD*'s Inaugural Professional Society Partner

The International Association for Quantitative Finance *(formerly the IAFE)* is the professional society dedicated to fostering the profession of quantitative finance by providing platforms for the discussion of cutting-edge and pivotal issues in the field. Founded in 1992, the IAQF is composed of individual academics and practitioners from banks, broker dealers, hedge funds, pension funds, asset management firms, technology firms, regulatory bodies, accounting, consulting and law firms, and universities across the globe.

Through frank discussions of current policy issues, hosting programs to educate the finance community, and recognizing the outstanding achievements in the field, the IAQF acts as a beacon for the development of quantitative finance. Throughout its history, the IAQF's pre-eminent leadership has positioned us to respond with savvy to the evolving needs of the financial engineering community. The IAQF's programs – from our area-specific committees to our evening forums to the Financial Engineer of the Year Award – are designed to provide our membership with uniquely valuable activities to enhance their work in the field.

Why Join the IAQF?

As ever more attention is focused on quantitative finance, the IAQF stands out as the leading professional society with a mission to address the timely and innovative issues in the field. Our membership represents an unmatched level of expertise.

IAQF Members Enjoy:

- **Access to exclusive content on our website**
  This includes access to the entire archive of the IAQF's former publication, the *Journal of Financial Engineering*.
- **Free attendance to IAQF Evening Forums**
  The IAQF holds monthly talks and panel discussions on pressing topics in the field of quantitative finance and the policy issues that are just around the corner.
- **Discounts to IAQF-Endorsed Conferences**
  As part of our educational mission, we endorse conferences that we believe our membership would value. Conference fees can be exorbitant and the discounts that our members usually receive often saves them a dollar amount exceeding the price of their IAQF membership.
- **Invitations to our Annual Award Dinner**
  Our highest profile event, our Financial Engineer of the Year Award Dinner offers a unique opportunity to socialize with people making significant contributions to the field.

The IAQF offers Student, Academic, Young Practitioner and Practitioner Memberships, as well as Academic Affiliate Memberships to Masters-level academic programs in Quantitative Finance/Financial Engineering/Mathematical Finance or similar fields of concentration.

For more information, please visit www.iaqf.org

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

The *Global Commodity Applied Research Digest* is produced by the J.P. Morgan Center for Commodities (JPMCC) at the University of Colorado Denver Business School. The JPMCC is the first center of its kind focused on a broad range of commodities, including agriculture, energy, and mining. Established in 2012, this innovative center provides educational programs and supports research in commodities markets, regulation, trading, financial fundamentals, investing, and risk management.

In addition to its education mission, the J.P. Morgan Center for Commodities' aim is to become a focal point for worldwide research on commodities.

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