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

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

SUMMER 2019

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GLOBAL COMMODITIES APPLIED RESEARCH DIGEST

Vol. 4, No. 1: Summer 2019

Index of Articles

TABLE OF CONTENTS
Vol. 4, No. 1: Summer 2019

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 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. The Director of the JPMCC is Dr. Yosef Bonaparte, Ph.D., who is also an Associate Professor of Finance at the University of Colorado Denver Business School. The JPMCC's Program Manager, in turn, is Mr. Matthew Fleming.

Director's Inaugural Welcome Letter

By Yosef Bonaparte, Ph.D., Director of the JPMCC and Associate Professor of Finance, University of Colorado Denver Business School

In his inaugural welcome letter, the Director of the JPMCC reviews the Center's mission and purpose; summarizes one of his recent research projects; and discusses a recent thought-leadership panel sponsored by the JPMCC. The director also welcomed reader feedback on how the JPMCC can make the *GCARD* as relevant as possible to commodity industry practitioners, consistent with the JPMCC's mission.

Research Director Report

By 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

This issue's Research Director Report covers the JPMCC's research outreach activities that took place during the latter half of 2018; introduces the JPMCC's newly named research affiliates; discusses the continued positive impact of the August 2018 international commodities symposium; and notes the Center's plans for the next international commodities symposium, which will take place in August 2019.

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. Advisory Council members also contribute practitioner-oriented 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 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.

CU Denver Business School

The J.P. Morgan Center for Commodities is housed at the University of Colorado Denver Business School. The Business School at CU Denver, in turn, offers industry-focused programs in commodities, energy, entrepreneurship, information & innovation, international business, risk management & insurance, and sustainability.

Research Council Corner

This article makes the case for why volatility is not the same as risk and then describes an alternative approach to risk assessment, which is illustrated with an example from the corn market. An important next step in the author's research process will be to make the new risk metrics, which are intuitively described in this paper, available publicly.

JPMCC Symposium Presentations

In modeling industrial commodity markets, this paper argues that changes in the volume of shipping of industrial raw materials are a better proxy for global real activity than changes in the overall real output of the global economy because they more accurately capture the timing and magnitude of shifts in demand. In contrast, in modeling food commodities such as wheat, corn, or rice, the article notes that a case can be made that demand depends on global real income, making world real GDP a potentially more suitable measure of global real economic activity.

JPMCC Symposium Presentations
(Continued)

Contributing Editor's Section

Advisory Council Analyses

Editorial Advisory Board Contribution

This paper compares the behavior of oil price volatility during two different time horizons: 1990 to 2003 and 2004 to 2018. The paper finds that the component of oil price volatility due to current information has diminished more quickly than previously while the systematic information component of oil price volatility has persisted longer than previously. The candidate hypotheses for why price volatility conditions have changed include fundamental changes in the markets such as the shale revolution, technology advancement, and geopolitics.

Regulatory Review

This article provides an extensive, data-driven analysis by the CFTC's Division of Market Oversight on the effects of the CME Group's introduction of block trading for the full suite of agricultural futures products.

Book Review

The authors of *Economics Gone Astray* make the compelling case that economists need to take their simplifying assumptions more seriously, to embrace statistical techniques that can track dynamic markets with time-varying parameters, and to always be aware of the importance of shifts in the underlying context. These concerns impact the analysis of financial and commodity markets alike.

Interview with a Leading Innovator in the Futures Markets

The *GCARD*'s interview with CME Group Chairman Emeritus Leo Melamed focuses on technological change in the financial markets. During the interview, the Chairman Emeritus discusses the wrenching move from floor trading to electronic trading, and he also provides his thoughts on the potential for disruptive change due to blockchain.

Editorial Advisory Board (EAB) Member News

This section summarizes the articles, journal appointments, and conferences that *GCARD* EAB members have recently contributed to or participated in.

CU Denver Business School Global Energy Management (GEM) Program

CU Denver Business School's commodity expertise includes not only the J.P. Morgan Center for Commodities, but also its Global Energy Management (GEM) program. The Business School's Master of Science in Global Energy Management program is a business and leadership degree, offered in a hybrid format that turns today's energy professionals into tomorrow's leaders. This degree prepares students to advance in their current field or to shift into a new role or sector.

SPECIAL FEATURE: Cutting-Edge Innovation in the Cryptosphere

By Rebecca Lewis, Former Analyst, Federal Reserve Bank of Chicago; John McPartland, Senior Policy Advisor, Federal Reserve Bank of Chicago; and Rajeev Ranjan, Senior Vice President, Citi and Former Policy Advisor, Federal Reserve Bank of Chicago

Blockchain technology is likely to be a key source of future financial market innovation. It allows for the creation of immutable records of transactions accessible by all participants in a network. This article provides a brief overview of what blockchain technology is, how it works, and some potential applications and challenges.

By Alex Cohen, Co-Founder and Managing Director, New Beacon Partners and Luis Quintero, Co-Founder and Managing Director, New Beacon Partners

This paper discusses three potential applications of blockchain technology, namely how the technology could be incorporated into (a) the current United States crop insurance industry, (b) supply chain logistics to help increase food safety and minimize the cost of food recalls, and (c) a new mechanism through which investors can gain direct exposure to commodities and commodity producing assets.

SPECIAL FEATURE: Cutting-Edge Innovation in the Cryptosphere
(Continued)

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

GLOBAL COMMODITIES
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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 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 at the University of Colorado Denver Business School. The Director of the JPMCC is Dr. Yosef Bonaparte, Ph.D., who is also an Associate Professor of Finance at the University of Colorado Denver Business School. Dr. Bonaparte is responsible for the day-to-day operations of the JPMCC, including its professional activities. The JPMCC's Program Manager, in turn, 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 covers topical issues in the agricultural, metals and mining, and energy markets as well as in commodity finance.

The *GCARD* has been made possible by a generous grant from the CME Group Foundation and is published twice per year. Complimentary subscriptions to the *GCARD* are available at: http://www.jpmcc-gcard.com/subscribe. Periodic updates on *GCARD*-related activities can be found at https://www.linkedin.com/company/jpmcc-gcard/.

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* benefits from the involvement of its distinguished Editorial Advisory Board. This international advisory board consists of experts from across all commodity segments. The board is composed of academics, researchers, educators, policy advisors, and practitioners, all of whom have an interest in disseminating thoughtful research on commodities to a wider audience. Board members provide the Contributing Editor with recommendations on articles that would be of particular relevance to commodity industry participants as well as author articles in their particular areas of commodity expertise.

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

Director's Inaugural Welcome Letter

Yosef Bonaparte, Ph.D.
Director of the J.P. Morgan Center for Commodities at the University of Colorado Denver Business School and Associate Professor of Finance, University of Colorado Denver Business School

At a JPMCC Research Council meeting, **Dr. Yosef Bonaparte**, Ph.D., Director of the J.P. Morgan Center for Commodities, welcomed industry participants bringing up challenges that they face, which could provide interesting puzzles for innovative research.

As Director of the J.P. Morgan Center for Commodities (JPMCC), I am pleased to welcome you to the seventh edition of the JPMCC's *Global Commodities Applied Research Digest*. I would also like to thank the CME Group Foundation and Mr. George Solich, President and CEO of FourPoint Energy, for their continued sponsorship of this publication and to express my gratitude to Chancellor Dorothy Horrell, Ph.D.; Acting Dean Jahangir Karimi, Ph.D.; and the JPMCC's Advisory Council for their unwavering support of the Center's research and educational activities. In addition, I would like to recognize former Dean Rohan Christie-David, Ph.D., for his work in building up the JPMCC's programs during the past two-and-half years.

In this inaugural letter, I will (a) review the JPMCC's mission and purpose, (b) summarize one of my recent research projects, and (c) discuss a recent thought-leadership panel sponsored by the JPMCC.

Mission of the J.P. Morgan Center for Commodities

For readers unfamiliar with the JPMCC, I would like to take this opportunity to introduce the Center to you. The JPMCC's activities encompass the business side of commodities. Through applied research and educational programs, we examine current issues and explore new ideas in the commodity markets.

The Center's core activities are as follows:

- *Education*: We train University of Colorado students in the business side of commodities. Our business school curriculum complements related programs such as the Colorado School of Mines and the University of Colorado Agriculture programs, which focus mainly on the physical production aspects of the commodities sector.

- *Applied research*: We conduct academic research that is of practical relevance to business practitioners.

- *Think tank*: We research and comment on current policy issues that are of concern in the commodity markets.

We carry out each of these core activities by partnering with the business community and other stakeholders in the energy, metals-and-mining, and agricultural markets.

Recent Research Project

One of my research interests concerns detecting potential political influences on oil prices, which was previously noted in the Fall 2016 issue of the *GCARD*. In a recent working paper, I looked into the impact that U.S. presidential elections may have on real oil prices over the time period, May 1958 to March 2018.

In summary, the paper demonstrates that real oil prices (West Texas Intermediate spot) are \$4.7 to \$9.7 lower under Democratic presidencies than Republican presidencies. The paper also finds that oil prices and volatility co-move with the presidential life cycle (seniority) and that prices are lower during second-term presidencies. The results are statistically significant and robust, including subsamples and accounting for business cycle fluctuations.

The paper also provides some possible explanations for why there has been a statistically significant difference in oil prices across Democratic and Republican presidencies, including (a) how each political party pursues a fundamentally different energy policy, (b) how the nature and influence of lobbying also changes across party-in-power boundaries, and (c) how OPEC, and specifically Saudi Arabia, may respond differently to Democratic versus Republican presidencies.

Thought-Leadership Industry Panels

In addition to the prestigious commodities symposium that our research director, Dr. Jian Yang, Ph.D., CFA, organizes each year, the JPMCC also hosts industry panels on topical issues, for which I am responsible. For example, in March 2019 we hosted an industry panel on crypto currencies. Our panel of experts included Colin Fenton of Blacklight Research and Co-Head of the JPMCC's Advisory Council; Andrei Kirilenko, Ph.D., of Imperial College Business School and Best Paper Award Winner at the JPMCC's 2018 International Commodities Symposium; and Bill Sinclair of SALT.

Crypto Currencies: What are They, and What is the Future?
A Panel Discussion, Moderated by Dr. Yosef Bonaparte
March 6th, 2019 12:00 - 1:00 PM

Colin Fenton is the managing partner and head of research at Blacklight Research LLC, a strategic adviser to senior leaders of corporations, institutional investment firms, and sovereign governments. Previously, Colin was managing director at J.P. Morgan Chase & Co., where he served as global head of commodities research and chief commodities strategist.

Dr. Andrei Kirilenko is the Director of the Centre for Global Finance and Technology, a visiting Professor of Finance at the Imperial College Business School, and a Research Fellow in the Financial Economics Programme of the Centre for Economic Policy Research (CEPR). Prior to joining Imperial in August 2015, he was a Professor of the Practice of Finance at MIT Sloan and Co-Director of the MIT Center for Finance and Policy. Prior to MIT, Professor Kirilenko served as chief economist of the U.S. Commodity Futures Trading Commission (CFTC) between December 2010 and December 2012.

Bill Sinclair is Chief Technology Officer and Interim President and CEO at SALT, where he is responsible for driving the strategic direction of the company, facilitating the development of a best-in-class software platform, and creating long-term enterprise value for shareholders. With more than 20 years experience in tech and software, Bill has managed IT departments and software development teams as well as executed on global strategies across industries including finance, energy and Internet of Things (IoT).

The next issue of the *GCARD* will cover the panelists' very informative insights. In the meantime, one can read the *GCARD*'s special feature on cryptoassets and blockchain in the Winter 2018 issue, which includes predictions on the adoption of blockchain in the physical commodity markets. In addition, readers can refer to the current issue's special report on innovations in the cryptosphere, which includes articles on how smart contracts and tokenized securities could be useful in the natural resource and commodity markets.

Conclusion

If you would like to learn more about the JPMCC and its research and educational activities, please explore our website, https://business.ucdenver.edu/commodities/ or contact us at Commodities.Center@ucdenver.edu. We also welcome your input on how we can make the *GCARD* as relevant as possible to commodity industry practitioners, consistent with the JPMCC's mission.

Thank you!

Best Regards,

Yosef Bonaparte, Ph.D.
Director, J.P. Morgan Center for Commodities and
Associate Professor of Finance, University of Colorado Denver Business School
Website: https://business.ucdenver.edu/about/our-people/yosef-bonaparte

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Endnote

Regarding Bonaparte (2019), I am thankful for the generous contributions of research assistants, Meghan Nemechek and Sheela Kailasam.

References

Bonaparte, Y., 2019, "Political Cycles and Oil Prices: Understanding the Geopolitical Oil Supply," University of Colorado Denver Working Paper.

"Special Feature: Cryptoasset and Blockchain," 2018, *Global Commodities Applied Research Digest*, Vol. 3, No. 2, Winter, pp. SF1-SF50.

"Special Report: Cutting-Edge Innovation in the Cryptosphere," 2019, *Global Commodities Applied Research Digest*, Vol. 4, No. 1, Summer.

Till, H., 2016, "The Determinants of the Price of Crude Oil: The Relative Importance of Fracking, China, and Geopolitics," *Global Commodities Applied Research Digest*, Reports on the Research Council Meetings, Vol. 1, No. 2, Fall, pp. 61-69. [Dr. Bonaparte was the academic discussant during the December 2015 JPMCC Research Council meeting that is summarized in this article.]

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

Dr. Jian Yang, Ph.D., CFA**,** J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Professor of Finance and Risk Management at the University of Colorado Denver Business School, presenting at the outset of the JPMCC's 2nd International Commodities Symposium on August 14, 2018.

This issue's Research Director Report will briefly cover (a) the JPMCC's research outreach activities that took place during the latter half of 2018, (b) our newly named research affiliates, (c) the continued positive impact of the August 2018 international commodities symposium, and (d) our plans for the next international commodities symposium, which will take place in August 2019.

JPMCC's Research Outreach Activities

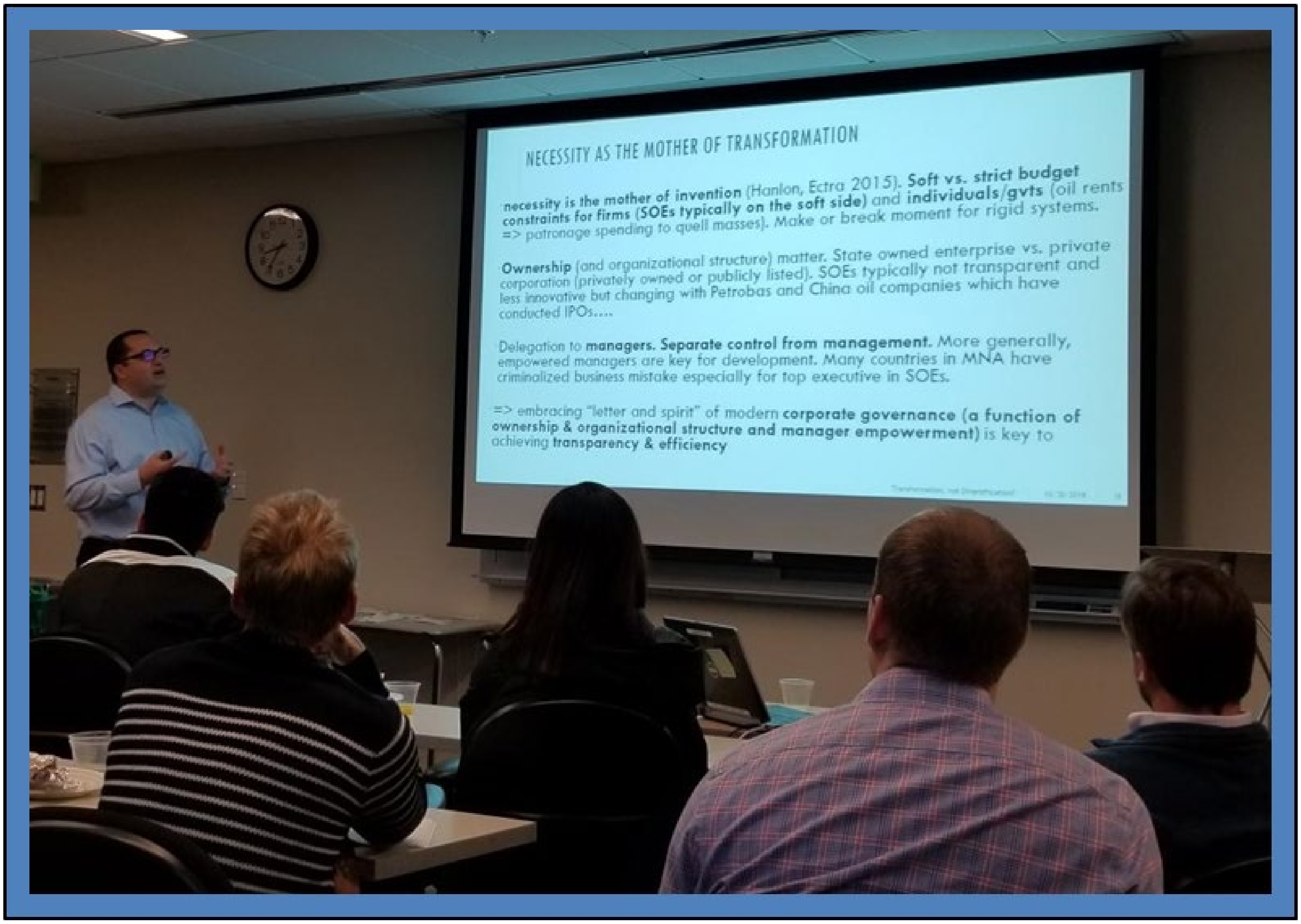
In line with our goal to become a focal point for worldwide research on commodities, we hosted two distinguished speakers in the Fall of 2018.

Dr. Craig Pirrong, Ph.D., Professor of Finance and Energy Markets Director for the Global Energy Management Institute at the Bauer College of Business, University of Houston, lectured on September 20, 2018 at the University of Colorado Denver Business School as part of the JPMCC's Encana Distinguished Speaker Series in Commodities. Dr. Pirrong is also a member of the JPMCC's Research Council.

On September 20, 2018, Dr. Craig Pirrong, Professor of Finance and Energy Markets Director for the Global Energy Management Institute at the Bauer College of Business, University of Houston, lectured on "Limited Only by the Imagination of Man: Commodity Market Manipulation Past, Present, and Future." Dr. Pirrong's presentation was sponsored by the JPMCC's Encana Distinguished Speaker Series in Commodities.

On October 30, 2018, Dr. Rabah Arezki, the Chief Economist for the Middle East and North Africa Region at the World Bank, lectured on "Economic Transformation, Not Diversification." Dr. Arezki had previously served as the Chief of the Commodities Unit in the Research Department at the International Monetary Fund. In his JPMCC lecture, Dr. Arezki explained why oil-producing countries must go beyond simply diversifying their economies. His presentation was sponsored by the JPMCC's Anadarko Petroleum Distinguished Speaker Series in Commodities.

Both distinguished lectures were well received by students, faculty, and business leaders.



Dr. Rabah Arezki, Ph.D., Chief Economist for the Middle East and North Africa Region at the World Bank, lectured on October 30, 2018 at the University of Colorado Denver Business School as part of the JPMCC's Anadarko Petroleum Distinguished Speaker Series in Commodities.

Leading Commodity Researchers Continue to Affiliate with the JPMCC

The JPMCC established the Distinguished Visiting Fellow program in 2018 to recognize leading researchers in commodities. The inaugural fellowship was awarded to internationally-recognized energy economist, James Hamilton of the University of California at San Diego, who is also the Co-Chair of the JPMCC's Research Council. We are proud to announce that our 2019 Distinguished Visiting Fellow is Dr. K. Geert Rouwenhorst, the Robert B. and Candice J. Haas Professor at Yale School of Management and Deputy Director of the International Center for Finance at Yale. Professor Rouwenhorst is also a member of the JPMCC's Research Council. His pioneering work on commodity investments has been very influential in establishing commodities as a suitable institutional investment. We are very grateful to both Dr. Hamilton and Dr. Rouwenhorst for their support of the JPMCC's mission.

K. Geert Rouwenhorst, Ph.D., Robert B. and Candice J. Haas Professor of Corporate Finance and Deputy Director of the International Center for Finance, Yale University, presenting "On Commodity Price Limits" at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018. Dr. Rouwenhorst is a member of the JPMCC's Research Council and is also the JPMCC's 2019 Distinguished Visiting Fellow.

In addition, the JPMCC recently implemented a Research Associates program to recognize younger active researchers in commodities and host their visits to the JPMCC and/or support their attendance at the annual JPMCC symposium. Our first appointment has been awarded to Dr. Sumudu Watugala, an Assistant Professor of Finance and the Bernard F. Stanton Sesquicentennial Faculty Fellow at the Dyson School of Applied Economics and Management at Cornell University. Congratulations to Dr. Watugala for this well-deserved recognition!

The Impact of the August 2018 International Commodities Symposium

The JPMCC's commodities symposium is becoming a premier event of its type internationally. For example, the October 2018 issue of *China Futures* magazine listed the 2018 JPMCC symposium as a news item together with news summaries from major global futures and options exchanges and national derivatives regulators such as the U.S. Commodity Futures Trading Commission (CFTC). In addition, the 2018 symposium will continue to promote the visibility of JPMCC to the academic world as the *Journal of Futures Markets* will publish a special issue in August 2019 that will feature five high-quality articles that were presented at the 2018 symposium. The articles, in turn, are coauthored by professors from Yale; Cornell; Manchester; Cass Business School, City, University of London; and by the CFTC's former chief economist. Further, the impact of the 2018 symposium on the local, national and international business community has recently been recognized by the award of the Laube Community Impact Award in November 2018 to the JPMCC's Research Director.

We are also pleased to see that the symposium is providing further opportunities for collaborating with presenters: two of the distinguished participants from the August 2018 symposium have co-authored digest articles for the current issue of the *GCARD.*

Planning for the 3rd JPMCC International Commodities Symposium in August 2019

Following the successful symposium in 2018, which included the participation of researchers from eight major countries, the JPMCC is organizing the 3rd annual international symposium at the University of Colorado Denver Business School, which will take place from August 12 through August 13, 2019. The upcoming symposium is drawing extensive attention from top scholars, policymakers and industry practitioners from around the world. Thus far, a partial list of confirmed participants includes chair professors from Yale and Stanford and industry leaders from Bosch GmbH, the CME Group, CoBank, and J.P. Morgan.

We have received paper submissions from academic researchers and policy researchers from (at least) thirteen countries, including Argentina, Australia, Canada, Chile, China, Denmark, France, Germany, India, Singapore, Spain, the U.K., and the U.S. (in an alphabetical order.) These submissions indicate a further increase in the interest of international participation as compared with the 2018 symposium. Not only have the number of submissions increased, and is more than three times as many as we originally planned to include in the regular paper presentation sessions this year, but these submissions are of high quality and are from authors whom are with leading academic and policymaking institutions. A partial listing of author affiliations includes Cornell, the Massachusetts Institute of Technology, UC-Berkeley, the University of Pennsylvania, the U.S. Federal Reserve, the International Monetary Fund, the Bank of Canada, the Central Bank of Chile, and the CFTC.

Of special note, we also gratefully acknowledge the strong support from the *Journal of Futures Markets* and its publisher, Wiley, for promoting the 2019 JPMCC symposium on its journal website and thus increasing the conference's visibility.

In closing, we very much look forward to welcoming you to this prestigious conference, as we showcase the vision and mission of the JPMCC, particularly within the research arena.

Best Regards,

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

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. The Advisory Council's Co-Chairs are Mr. Christopher Calger, Managing Director, Global Commodities, J.P. Morgan; and Mr. Colin Fenton, Managing Partner and Head of Research, Blacklight Research LLC.

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!

During the JPMCC's inaugural Research Council meeting, Advisory Council members, **Dr. Bluford Putnam**, Ph.D., Chief Economist of the CME Group, and **Mr. Lance Titus**, Managing Director, Uniper Global Commodities, are flanked by (left) Dr. Marcelle Arak, Ph.D., Professor of Finance Emerita, University of Colorado Denver Business School and (right) Dr. Robert Vigfusson, Ph.D., Chief, Trade and Quantitative Studies Section, Board of Governors of the Federal Reserve System. The meeting was held at the University of Colorado Denver Business School's CoBank Lecture Hall.

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.

Michel Robe, Ph.D., The Clearing Corporation Foundation Professor in Derivatives Trading, University of Illinois at Urbana-Champaign, presented on "Who Holds Positions in Agricultural Futures Markets? Evidence from Regulatory Data" at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2018. Dr. Robe is also 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

Dr. Sueann AMBRON *J.P. Morgan Center for Commodities*	**Matthew MOST** *Encana*
Thorvin ANDERSON, CFA *Razor Commodity Advisors, LLC*	**Nikos NOMIKOS, Ph.D.** *Cass Business School, City, University of London (U.K.)*
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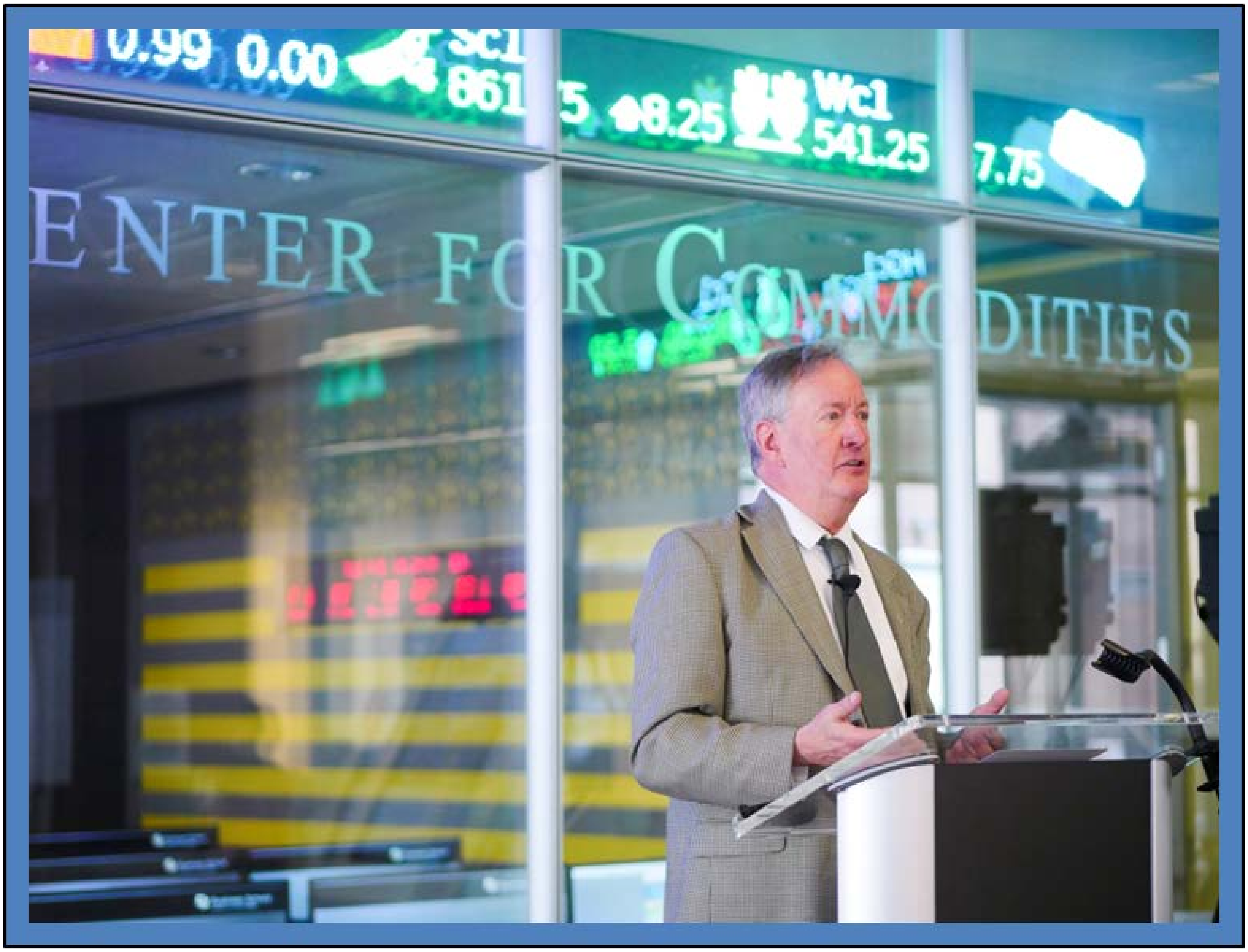
Vince KAMINSKI, Ph.D. *Rice University*	**Robert VIGFUSSON, Ph.D.** *Board of Governors of the Federal Reserve System*
Lutz KILIAN, Ph.D. *University of Michigan at Ann Arbor*	**Robert WEBB, Ph.D.** *University of Virginia*
Dan KOWALSKI *CoBank*	**Brian WRIGHT, Ph.D.** *University of California, Berkeley*
Benjamin LEE, Ph.D. *National Renewable Energy Laboratory*	**Wei XIONG, Ph.D.** *Princeton University*
Peter McCALLUM *Bunge Limited*	

Commodity Risks: Describing the Unobservable

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



Dr. Bluford Putnam, Ph.D., Chief Economist, CME Group, and member of the J.P. Morgan Center for Commodities' (JPMCC's) Research Council, presented on "Expected Risk-Return Probability Distributions: Important Differences between Commodity and Financial Markets" at the JPMCC's 2^{nd} International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2018.

We have observed in studying commodity markets that 100-year floods occur quite often, even multiple times a decade, so we know simple risk models can be inadequate and misleading. The challenge is that expected risk-return probability distributions cannot be directly observed. Some analysts lean heavily on examining the implied volatilities from options prices. Unfortunately, the implied volatilities all too often underestimate what is happening in the extremes of the distribution where the high impact risks are located.

Our view is that we should explore much more robust measures of risk. We need to appreciate that volatility is not the same as risk, and that the standard deviation is a very poor risk metric on which to rely so heavily. Our approach is to go beyond futures and options prices and include information from volumes and intra-day activity in our methodology to allow for multiple scenarios which avoid the bias toward the bell-shaped distributions that appear highly flawed relative to historical experience.

In this research, we first briefly make our case for why volatility is not the same as risk. We then tackle the question of why the implied volatilities derived from options prices can also be a dangerous and misleading risk metric. Then, we intuitively describe our approach and apply it to an example from the corn market to give readers a flavor of our research approach.

Volatility is Not Risk

Many analysts like volatility because the historical standard deviation is easy to calculate and fits nicely into basic risk systems and mean-variance portfolio models. The problem is that a trader, a commodity producer, or a commodity consuming commercial corporation may have asymmetrical risk preferences, preferring to avoid substantive losses rather than to make large gains. That is, if avoiding large losses is the primary risk, then a symmetrical standard-deviation based metric that only looks at the average noise level and not the extremes is certainly not appropriate. Your head is in the oven and your feet are in the freezer – on average one feels fine – and the standard deviation tells you that the risks are manageable when they may be quite dangerous for your long-term survival.

Moreover, volatility does not appropriately capture the nature of many risks when there are large uncertainties (Putnam *et al.*, 2019). We want to appreciate the behavioral patterns related to reacting to uncertainty. The science of fear often sees patterns of behavior that bear a strong resemblance to chaos theory (Gleick, 1987), and these observations may help explain the conundrum of why it is possible for elevated levels of uncertainty to co-exist with relatively low levels of market volatility.

Pretend you find yourself walking down a deserted road late at night, and you are more than a little concerned about your safety. You hear footsteps behind you. You keep on walking. The footsteps are getting closer. Your fear level is rising, and yet you keep on walking. As the footsteps get ever-nearer, perhaps you hear a sound or some catalyst, your fear reaches a point where you face a decision to turn and confront the challenge (if there is one) or run away. Once you choose, there will be no going back.

These are among the types of decisions analyzed by chaos theory. Rising fears, or uncertainties, do not trigger a change in behavior. A reaction to the rising fears takes a catalyst; fear or uncertainty alone is not a cause of volatility, yet is a source of perceived risk. In our example, the footsteps get so close as to force a decision about what action to take. And, once the decision is made, you are committed to the new path. By way of another illustration, the same thing happens on a ski slope. You are at the mountain top and resting on your skis peering down the steep expert slope. You could take the bunny slope down or you could push off on a wild ride. Once the decision is made to tackle the steep slope, there will be no turning back.

What we observe is that the uncertainties are well appreciated, from technology, demographics, social change, as well as from the current policy issues such as taxes, trade, and monetary policy. The catalyst only arrives when something actually happens that changes the consensus view from worrying about uncertainties to taking actions to manage the risks associated with the potential market-moving events.

The Dangers of Relying Primarily on Implied Volatility as a Risk Metric

Another challenge is that implied volatilities are typically calculated from straightforward options pricing models that embed the heroic assumption that prices move up or down with continuous trading – that is, price breaks or price gaps are assumed never to occur. If market participants fear the possibility of price breaks or gaps, options prices will reflect this risk and the result is a higher calculated implied volatility. But it will not be easily apparent that the implied volatility is reflecting price gap risk instead of an upward shift in the volatility regime. And, price gap risk is not the same risk as volatility regime shift risk. Depending on one's financial exposures, one of these risks could be much more important than the other. For those managing options portfolios, for example, the risk of an abrupt price break can do considerable damage to delta hedging strategies while a volatility regime shift represents a different risk, commonly known as "vega" risk. What one needs to create is a comprehensive view of the whole risk probability distribution providing a robust perception of risks, allowing for decidedly different risk scenarios, and not being biased toward bell-shaped curves.

Our conclusion is that starting from a standard deviation approach, such as implied volatility, may inadvertently make it very hard to estimate when extreme and highly dangerous risk distributions are present. The math behind this observation is quite old and goes back to the Russian mathematician, Pafnuty Lvovich Chebyshev (1821 – 1894). What most people take away from Chebyshev's Inequality Theorem is that if you know only the standard deviation you have a very good idea of the typical ranges in which values will fall most of the time. What we take away from the Inequality Theorem is that if you only know the standard deviation, you know absolutely nothing about the extremes of the distribution where the most dangerous risks reside. In short, one should look well beyond options prices and implied volatility to achieve a robust description of the unobservable risk-return probability distribution.

Attempting to Estimate Unobservable Expected Probability Distributions

From a practical perspective, our methodology starts with a Bayesian prior (i.e., our initial view of the world before examining any data) of an abnormal, bimodal risk probability distribution. We know if we start from the point of considering two highly divergent scenarios, and then let the observed data take us back to a bell-shaped curve or leave us with bimodality, that we have not ruled out or overly biased our analysis to always provide the bell-shaped curves, which are known to underestimate the extreme risks inherent in the tails of the distribution.

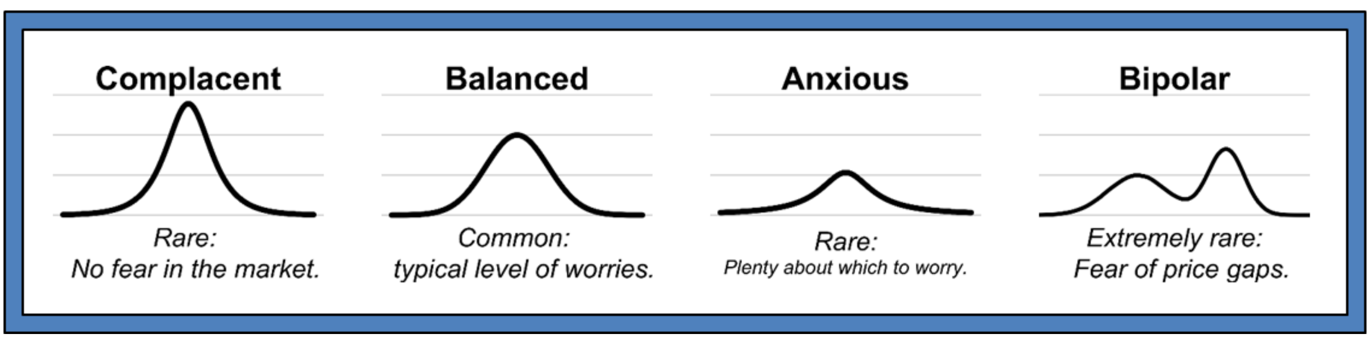
Our research is still at the early stages and is being conducted in partnership with 1Qbit, a quantum consulting and software development company, focused on solving difficult artificial intelligence and machine learning problems. So far, we have found a few metrics that are especially enlightening relative to the shape of the probability distribution. Our three primary metrics are: (1) the evolving pattern of put option trading volume relative to call option volume, (2) intra-day market activity, especially high/low spreads, and (3) implied volatility from options prices relative to historical volatility.

Studying put/call volume patterns helps us understand if one side of the market is more at the center of the current debate than the other side. For example, immediately after former Federal Reserve (Fed) Chair Ben Bernanke threw his famous "Taper Tantrum" in May 2013, he set off a debate about when the Fed would withdraw quantitative easing (QE) and raise interest rates. Put volume on Treasury note and bond prices soared relative to call volume indicating that a two-scenario situation had developed. While there is a buyer and a seller for every trade, one side thought prices would fall (yields rise) and volatility might rise very soon (buyer of puts) while the other side thought the process of exiting QE would take a long time (seller of puts).

Intra-day market dynamics help us appreciate risk in a different way. The observed high price to low price intra-day trading spread is informative in helping us assess the degree to which fat-tails might be present. Mathematically, work by Mark B. Garmen and others back in the 1970s and 1980s has shown that if one assumes a normal distribution then there is a straightforward way to estimate the standard deviation of daily returns from the intra-day high-to-low spread. Put another way, if the relationship between intra-day dynamics and the day-to-day standard deviation diverge in a significant manner, then this is strong evidence that the risk probability distribution is not normally distributed.

To ascertain the risk of price breaks we track the evolving pattern of implied volatility relative to historical volatility. While it is usual for implied volatility to exceed recent historical standard deviations, a shift in the pattern toward a much higher implied volatility may indicate that expectations for the potential of a sharp price break are building in the market. And, if a price break occurs, scenarios resolve one way or the other, so we often see a quick decline in the implied volatility representing a shift back to a single-mode bell-shaped distribution.

Figure 1
Four States of Market Participants' Perceptions of Risks



To gather all our risk information and create a probability distribution, we use a probability mixture technique that is distribution independent – that is, it is not constrained to take on a given specified shape. Most of the time, bell-shaped curves are appropriate descriptions of the probability distributions – balanced risk distributions. Our method does, however, occasionally generate some especially tall distributions (i.e., relatively lower volatility), which we classify as "complacent" and worthy of special study to see if the market may be underestimating risks. We also see on occasion some very flat distributions, not unlike the Wall Street maxim about the equity markets "climbing a wall of worry," which we call "anxious" risk distributions. And, finally, on rare occasions our metrics support the idea of a two-scenario, event-risk bimodal distribution. That is, we classify expected risk distributions into four types: "Complacent" which are very tall and thin, "Balanced" risks with a typical bell-shape, "Anxious" reflecting a relatively flat bell-shape with very fat tails and possibly skewed one way or the other, and finally our bimodal (aka, "Bipolar") or event risk distribution which are trying to anticipate what happens if one of two very divergent scenarios is the outcome. Figure 1 on the previous page illustrates these four types of risk distributions.

Illustration with a Case Study from the Corn Futures and Options Markets

To illustrate our probability risk distributions, we take a case covering a very interesting evolution of risk perceptions in the corn market in late 2012 and into the first half of 2013. The summer of 2012 had seen large swaths of the US corn belt experience severe drought, as illustrated in Figure 2 on the next page. Late in 2012, after the harvest, market participants' thoughts turned to the 2013 crop, about which there was much disagreement. How much acreage would be planted after the drought year? Would 2013 see another drought or its disappearance? While not of the political version of event risk, corn market participants were worried about the drought continuing and a two-scenario market developed for a while in February 2013 as one side of the market took the view that the 2013 crop would be much better than 2012's drought-constrained crop and other market participants worried about another poor crop. Our probability risk distribution was already in an "anxious" state late in 2012, shifted to "event risk" in February 2013, went back to "anxious" for most of the spring of 2013, before returning to the most common state, "balanced risks" in the summer of 2013. Figures 3 and 4 illustrate the corn market's shifting risk perceptions while Figure 5 provides the drought's impact on corn prices. Please see the following two pages.

Figure 2:
Drought Monitor for August 2012

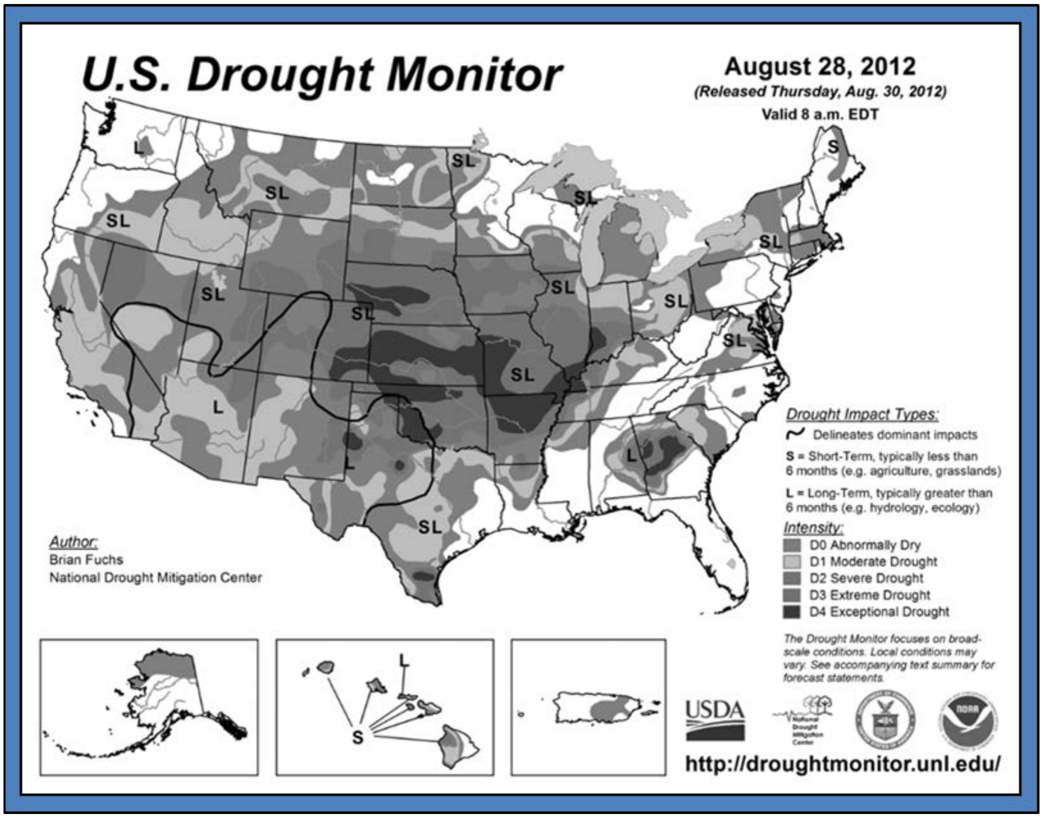


Figure 3:
Corn Market Risk Perceptions: February 15, 2013

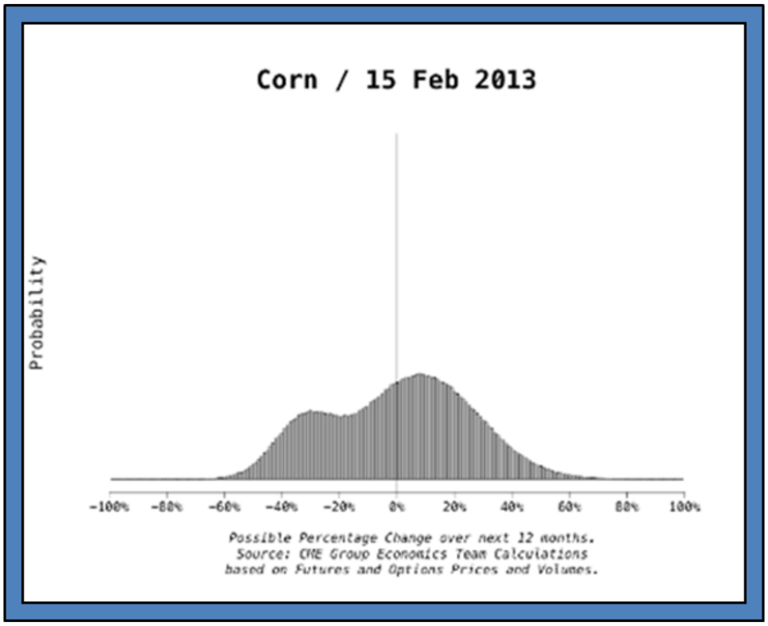


Figure 4:
Corn Market Risk Perceptions: September 16, 2013

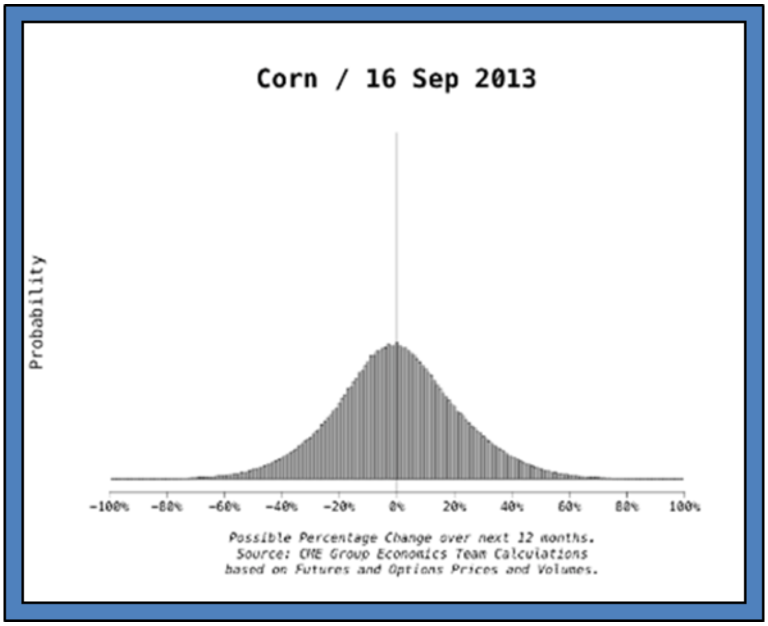


Figure 5:
Corn Futures Prices

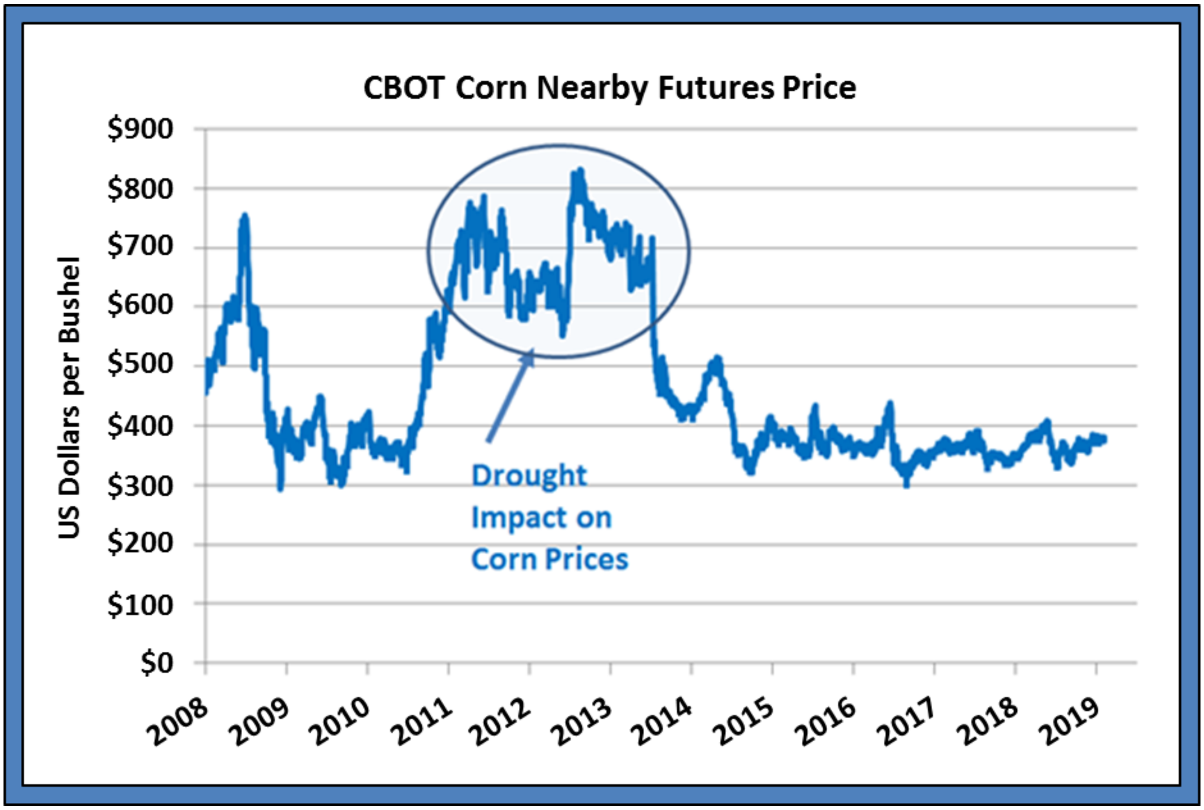


Chart created by CME Group Economics Team.

Data Source: Bloomberg Professional (LC1).

While this case study from the corn markets was presented purely as an illustration, our research methods allow for the rarest of market states – bimodal probability distributions – to occur in all of the product classes we have studied so far, which includes the commodity markets discussed here as well as our research in financial markets such as U.S. Treasury Note futures, equity index futures, and the Euro (versus USD). We believe it is important to monitor our risk states, especially when they shift from one category to the next. We do not expect the most common state – "balanced risks" occurring as much as two-thirds to three-quarters of the time, depending on the product, to provide any critical information that one would not acquire looking only at implied volatilities from options markets. We do think, however, that when the probability risk distribution shifts into a less typical state – "complacent", "anxious", or especially "event risk" – that risk managers should go on high alert. We also warn that while our naming conventions describe the risk distributions, they may not describe what happens. "Complacent" states may well be followed by volatility when some new and unexpected risk factor takes priority. "Anxious" states may or may not overstate fears, as equity analysts talk about when they say "a market is climbing a wall of worry". "Bipolar risk" states do not last long, as they tend to be resolved back to a one-scenario, single-mode distribution when the event occurs, and the outcome becomes known or when market participants become more confident that a one-scenario outlook with appropriate skepticism is more appropriate than a two-scenario approach.

An important next step in our research process will be to make our probability risk metrics available publicly. Through a partnership with 1Qbit (https://1qbit.com/), a software company specializing in solving some of the most difficult and intractable problems, curated daily data sets will be forthcoming on CME DataMine (https://www.cmegroup.com/market-data/datamine-historical-data.html). The data sets will cover eight exchange-traded futures and options products, including CME E-Mini S&P500®, CBOT U.S. Treasury 10-Year Note, CME Euro FX, NYMEX WTI crude oil, NYMEX Henry Hub natural gas, COMEX gold, CBOT soybeans, and CBOT corn. Data will go back to January 2012.

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.

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How to Measure Global Real Economic Activity when Modeling Commodity Prices

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Professor Lutz Kilian, Ph.D., University of Michigan, Ann Arbor, and member of the J.P. Morgan Center for Commodities' (JPMCC's) Research Council, presenting at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2018. From left-to-right are Dr. Kilian's fellow presenters at the JPMCC's Economics of Energy Markets panel: Dr. Reinhard Ellwanger, Ph.D., of the Bank of Canada and Dr. Hinnerk Gnutzmann, Ph.D., of Leibniz Universität Hannover (Germany). Dr. Ellwanger, in turn, also contributed an article to this issue of the *GCARD* on his JPMCC presentation.

Introduction

Indicators of global real economic activity are of central importance in modeling real commodity prices. They also play an important role in forecasting commodity prices, in studying the effects of commodity

The JPMCC's August 2018 International Commodities Symposium was organized by Professor Jian Yang, Ph.D., CFA, the JPMCC's Research Director.

price shocks on commodity importers and exporters, in assessing the role of speculation and financial market integration, and in identifying short-run price elasticities in commodity markets.

Since Barsky and Kilian (2002), it has been widely understood that shifts in the consumption demand (also known as flow demand) for commodities are an important determinant of both real commodity prices and global real economic activity. What is not always appreciated by practitioners and economists is that global real activity is not a proxy for the global flow demand for commodities. An increase in global real activity, for example, may result from a positive oil supply shock or a positive shock to the flow demand for oil and other commodities. Thus, not every increase in global real activity reflects higher flow demand. Moreover, there is more than one demand shock in commodity markets. Other examples include shocks to the demand for storage driven by price expectations and preference shocks for particular commodities. Each of these shocks has different implications for global real activity that need to be taken into account.

Uncovering latent shifts in the flow demand for commodities thus involves disentangling all demand and supply shocks that jointly drive real commodity prices and global real activity. This requires estimating a structural model of the commodity market based on an appropriate measure of global real activity. Thus, the question of how to measure global real activity is crucial when modeling commodity prices.

What Makes a Good Indicator of Global Real Economic Activity?

Many macroeconomists still believe that conventional measures of global real Gross Domestic Product (GDP) or global industrial production already used in macroeconomic models of the global economy are also well suited for modeling and understanding real commodity prices. This is not the case. A recent study by Kilian and Zhou (2018) explains what properties an index of global real activity must satisfy to be useful for modeling industrial commodity prices:

- The coverage of the index must be global.

- The index must span a long enough time period to facilitate the estimation of structural models of commodity markets.

- Monthly indices are preferred because the use of monthly data facilitates the imposition of identifying assumptions in structural models of commodity markets.

- The index must account for the fact that over time, the share of the industrial sector in output has declined while that of the services sector has increased.

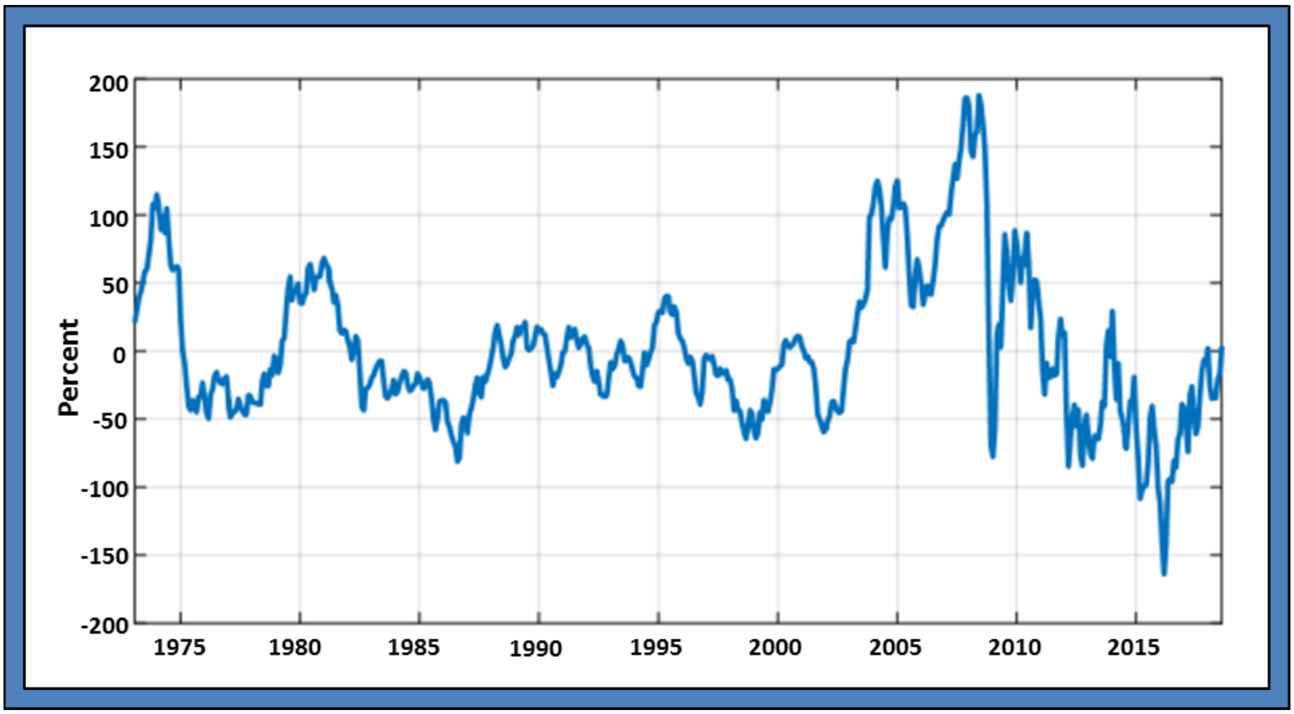
- The index must be a leading indicator for industrial production. This requirement follows from the fact that inputs must be ordered and shipped before starting the production process. Because shipping takes time, the index must be a leading indicator for global industrial production. An immediate implication is that the amplitude of fluctuations in this leading indicator reflects firms' expectations of future production, so both the timing and magnitude of the index may differ from conventional real output proxies.

- Finally, if the index is to be used for out-of-sample forecasting, it must also be available in real time.

How Do Existing Proposals for Measuring Global Real Activity Stack up by These Criteria?

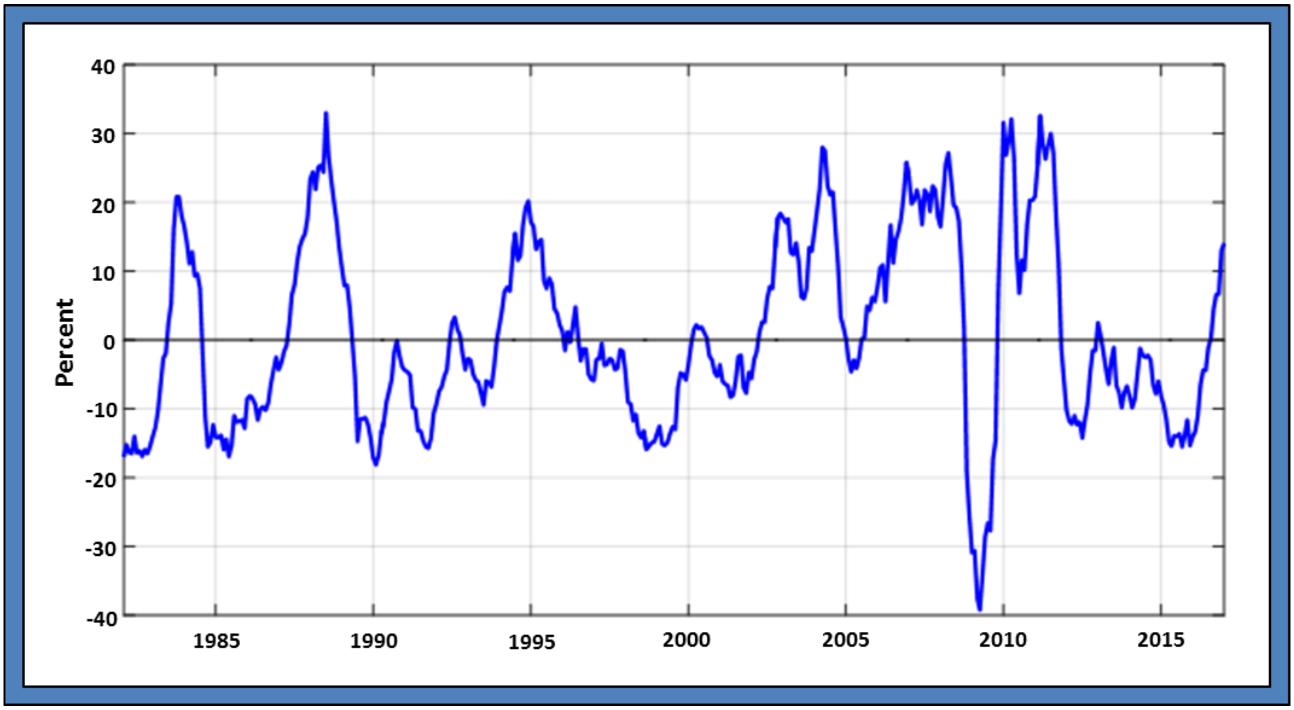
There have been many proposals for measuring global real activity including global real GDP, global industrial production, world steel production, measures of fluctuations in the volume of ocean freight shipping, and common factors in real commodity prices. Only two of these proposals, however, satisfy all six of the criteria laid out above. One is the index of global real economic activity proposed by Kilian (2009), which is designed to measure cyclical variation in the volume of the shipping of bulk dry cargoes such as iron ore, coal, fertilizer and scrap metal (see Figure 1 below). The other is indices based on the common factor in the real prices of commodities that are traded globally, as proposed by Alquist and Coibion (2014) and Delle Chiae *et al*. (2016) (see Figure 2 on the next page).

Figure 1
Updated Kilian (2009) Index of Global Real Economic Activity, 1973.1-2018.7



In contrast, quarterly global real GDP is a poor measure in this context because of the increasing importance of the service sector in the global economy and because a monthly index is preferred over a quarterly index. While global monthly industrial production does not suffer from these two limitations, proxies for global industrial production are not leading indicators for global real output, making global industrial production poorly suited for modeling commodity markets. Likewise, world steel production cannot be recommended because changing the global coverage of this index results in jumps in the index, and because it is another coincident indicator rather than a leading indicator.

Figure 2
Global Real Commodity Price Index of Delle Chiae *et al*. (2016) in Year-on-Year Growth Rates



What Are the Drawbacks of the Kilian Index of Global Real Activity?

As the popularity of the Kilian index of global real activity has grown, a number of objections to this index have been raised. One claim has been that this index should not be used because exogenous increases in the real price of oil raise the cost of the bunker fuel used to run bulk dry cargo vessels and hence raise the bulk dry cargo shipping rates from which the Kilian index is constructed, making it impossible to identify shifts in the volume of bulk dry cargo shipping.

It can be shown that this claim is invalid. Not only is the link from oil prices to bunker fuel rates much weaker than sometimes thought, but time charter shipping rates, as captured by the Baltic Dry Index (BDI) used in the construction of the Kilian index since 1985, do not respond to changes in bunker fuel. The reason is simple. Time charter rates refer to the rate charged by the owner for leasing a vessel for, say, one year. Since the lessee is responsible for the fuel charges incurred when running this vessel, increases in bunker fuel prices do not affect the rate charged by the owner of the vessel.

A similar conclusion is reached, if we are relying on single voyage rates, as the Kilian index did prior to 1985. Single-voyage rates refer to the rate charged for moving a vessel from one port to another port (say, an iron ore freighter from Brazil to China). In that case, we know from industry sources that the owner sets the shipping rate based on the fuel costs in the preceding quarter, making the single-voyage rate predetermined with respect to the changes in the price of oil. Thus, feedback may occur only with considerable delay.

Moreover, since the Kilian index looks much the same whether it is constructed from time-charter or single-voyage rates, the claim of reverse causality from oil prices to the index can be easily rejected. This means that the well-documented positive co-movement between the real price of oil and the Kilian index simply results from flow demand shocks simultaneously raising global real activity and the real price of oil.

Another claim has been that the Kilian index is distorted by changes in the stock of bulk dry cargo vessels. This claim as well can be refuted. First, changes in the bulk dry cargo fleet are too smooth to explain the variability of the Kilian index. Second, it can be shown that the changes in real shipping rate match quite closely annual data on changes in the tonnage of bulk dry cargo, when such data are available, suggesting that the index is a good measure of changes in the volume of seaborne bulk dry cargo trade. Third, the cyclical decline in the Kilian index since 2011, which originally prompted the concern about changes in the fleet size, is corroborated by a wide range of alternative proxies for global real activity that do not depend on data from shipping markets.

A third claim has been that the Kilian index has been excessively volatile, especially in early 2016, when the index shows a negative spike for two months (see Figure 1). This concern is driven by the common misperception that the evolution of the Kilian index should somehow match that of measures of global real output. As noted earlier, this is not the case because the Kilian index may respond to fluctuations in expected real output that never materialize in actual real output. Thus, there is no reason to expect the Kilian index to mirror subsequent fluctuations in real output, although often it does. Nor is there a mystery as to the origin of the negative spike in early 2016, which can be traced to a temporary drop in the demand for iron ore and coal from China that is not reflected in subsequent drops in steel production or industrial production and hence appears based on expectations that did not materialize.

Finally, it should be noted that the Kilian index, as shown in Figure 1, is consistent with what we know from extraneous sources about the global business cycle in commodity markets since the 1970s. It is also consistent with information from recent survey data about the global economy and highly correlated with survey data for export orders. Recently, it has been suggested that one could have expressed real bulk dry cargo freight rates in 24-month cumulative growth rates rather than removing a linear time trend, as proposed by Kilian (2009). The resulting time series, however, makes no economic sense as a measure of the global business cycle. It implies a recession in 2005, when the global economy was booming and a protracted recession after 2009, when real commodity prices and the global economy recovered sharply.

What Are the Drawbacks of Real Commodity Price Indices?

Likewise, common factors extracted from real commodity prices, as shown in Figure 2, are not without limitations. First, not all important commodities are freely traded. For example, before 2009 iron ore was not freely traded. Second, there is no consensus yet on how to select the real commodity prices from which the common factor is extracted and how to extract that factor. Which way this is done also affects for how long real commodity price indices may be constructed. Finally, constructing these indices may require additional smoothing. Researchers have made different choices in that regard.

Did Global Real Activity Slow Down after 2011?

One of the implications of the Kilian index in Figure 1 as well as the real commodity price index in Figure 2 is that there was a sustained slowdown in global real activity starting in about 2011. This pattern is consistent with the sustained decline in many real commodity prices (see Table 1). Such a broad-based decline is unlikely to be explained by favorable supply shocks in individual commodity markets. Even for crude oil, we know that supply shocks have been of limited importance in explaining the decline in the real oil price (see Kilian, 2017).

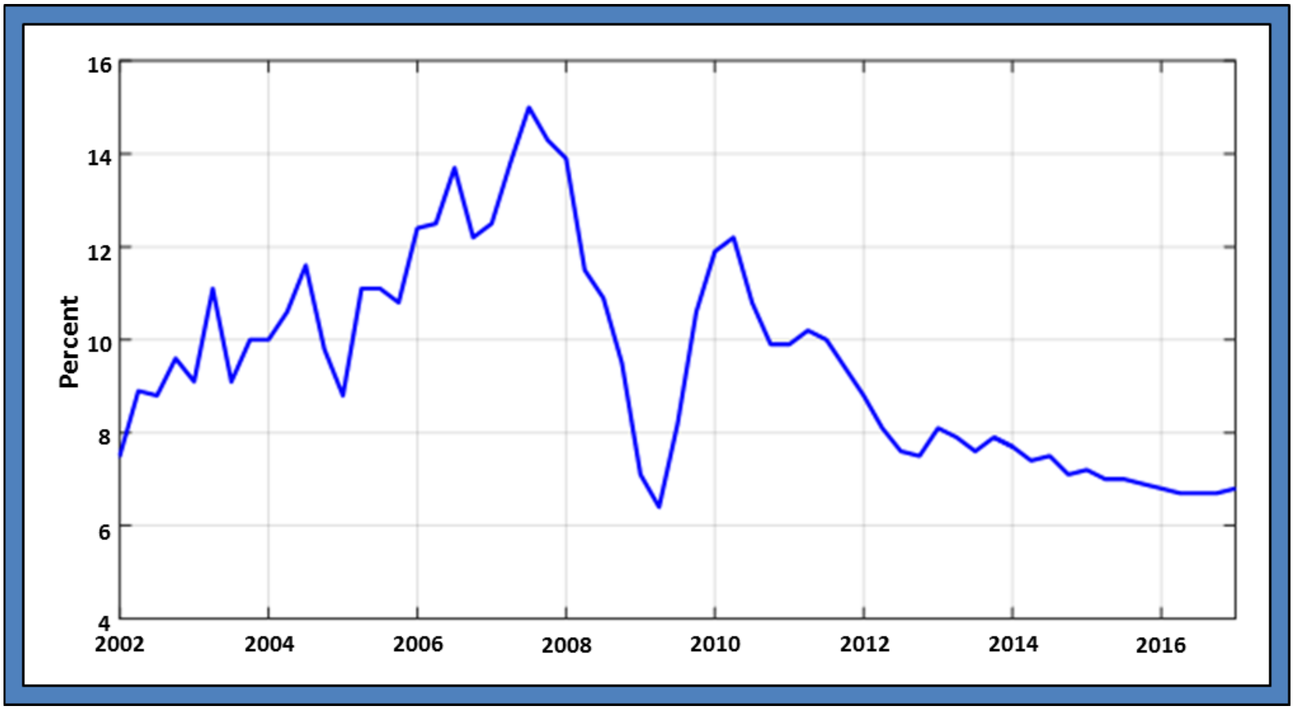
Table 1
Cumulative Changes in Real Commodity Prices, 2010.5-2015.12

Global Commodity Price Indices	Cumulative Change in Real Price (%)
Industrial Raw Materials Price Index	-40.93
Metals Price Index	-51.46
Copper Price	-38.12
Iron Ore Price	-76.87
Brent Price of Crude Oil	-54.32

Given that the surge in commodity prices in the 2000s was associated with an economic expansion in emerging Asia led by China, a natural conjecture is that this decline reflected a slowdown of China's economy. Figure 3 on the next page supports this conjecture. There is clear evidence of high year-on-year growth rates from 2002 to 2007, followed by a sharp decline during the global financial crisis, and a partial recovery in 2009. Since 2011, however, year-on-year growth has been sliding to levels last seen during the financial crisis or in 2002. Arguably, the official Chinese data understate the true extent of the decline after 2011, but the pattern is clear even in the official data. Similar patterns are also found in data on Chinese electricity production and industrial value added.

This evidence, in conjunction with survey data on the global economy as well as proxies for global real output, confirms that global real activity by 2016 was back to where it had been before the surge in global real activity that started in 2002. In other words, the boom in emerging Asia appears to have been largely transitory, in contrast to the perception of many observers in the 2000s who regarded the Asian boom as a permanent shift in the global economy.

Figure 3
Year-on-Year Growth in China's Real GDP



The slowdown in global real activity after 2011 may be related to a reduction in overall trade growth from 7.4% at annual rates during 1995-2007 to 3.1% during 2012-15. At the same time, the income elasticity of trade for emerging economies also fell from 1.5 to 0.8. The decline in the volume of bulk dry cargo shipping, in particular, may also be explained by the increased importance of the service sector, slowing growth in infrastructure, and the increased reliance of the Chinese economy on domestic consumption rather than exports.

This point has important implications for commodity exporters and for commodity price forecasting. Interestingly, the partial recovery in the Kilian index since mid-2016 back to the long-run average is not driven by China, but apparently reflects an economic expansion in the United States, Japan and Europe.

Concluding Remarks

Differences in how one measures the global business cycle can easily affect conclusions about the timing and magnitude of an economic slowdown or expansion, and using inappropriate proxies is likely to distort estimates of commodity market models and of price elasticities. Our analysis supports the use of indices of real activity derived from dry bulk cargo freight rates such as the BDI as well as the use of indices based on real commodity prices, but raises concerns about the use of measures of world real GDP and of global industrial production.

This does not mean that traditional measures of world real GDP or world industrial production should never be used in empirical work, but rather that the intended use of these time series matters. Data that are appropriate for modeling cyclical fluctuations in global real output in macroeconomic models, for example, may not be appropriate for identifying shifts in the demand for global commodities, and conversely many indicators of global real economic activity in the literature are poor measures of fluctuations in global income.

We explained why, in modeling industrial commodity markets, changes in the volume of shipping of industrial raw materials are a better proxy for global real activity than changes in the overall real output of the global economy because they more accurately capture the timing and magnitude of shifts in demand. In contrast, in modeling food commodities such as wheat, corn, or rice, the case can be made that demand depends on global real income, making world real GDP a potentially more suitable measure of global real economic activity.

Endnotes

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.

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The Simple Economics of Global Fuel Consumption: Digest Version

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Reinhard Ellwanger, Ph.D., Bank of Canada, presenting at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2018. From left-to-right are Dr. Ellwanger's fellow presenters at the JPMCC's Economics of Energy Markets panel: Dr. Hinnerk Gnutzmann, Ph.D., Leibniz Universität Hannover (Germany) and Dr. Lutz Kilian, Ph.D., University of Michigan, Ann Arbor. Dr. Kilian, in turn, also co-authored an article in this issue of the *GCARD*.

Understanding the Role of Fuel Consumption in the Global Market for Oil

A common view among practitioners and policy makers is that the demand for crude oil is ultimately derived from the demand for oil products. The view rests on the fact that crude oil has no use in and of itself, but is used as a feedstock in the production of fuel and other petrochemical products (henceforth

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The JPMCC's August 2018 International Commodities Symposium was organized by Professor Jian Yang, Ph.D., CFA, the JPMCC's Research Director.

jointly referred to as fuel).[1] Thus, consumption of oil takes place in the form of fuel. Fluctuations in global fuel consumption bear important consequences not only for oil prices and the global economy, but also for environmental policies. In this digest article, we summarize the paper[2] that Dr. Ellwanger presented at the J.P. Morgan Center for Commodities' 2nd International Commodities Symposium.

Our paper uses data on global fuel consumption to isolate the role of fuel demand shocks in the global oil market. Oil consumption, production and prices are driven by shocks to flow demand, flow supply, and storage demand. Each of these shocks has a different impact on the oil market and the broader economy. We propose a simple structural framework that measures the importance of each of these drivers and that is useful for policy analysis and forecast scenarios.

Measuring Oil Consumption, Production and the Market Balance

The empirical implementation of our model relies on a measure of global fuel consumption provided by the International Energy Agency (IEA). The series tracks total global oil product consumption, which includes all common uses of fuel, including as combustible and as petrochemical feedstock. The corresponding oil production series, also provided by the IEA, is based on a broad definition of oil production that includes not only crude oil, but also other refinery feedstock, blendstock and biofuels. The broad measure of oil production ensures that consumption and production are directly commensurate.

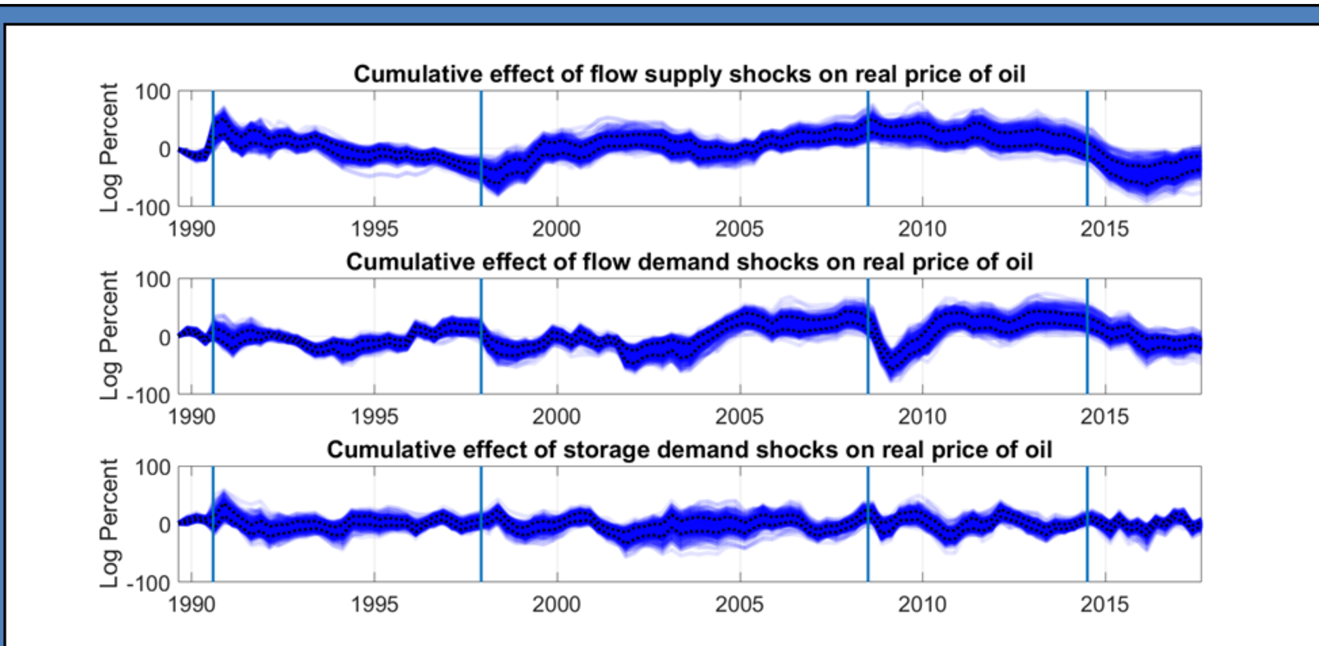
By identity, the difference between total oil production and total oil consumption amounts to the total change in oil inventories. In contrast to most of the existing literature of the oil market, which has focused on only crude oil inventories, this total change in oil inventories also includes changes in inventories of other refinery feedstocks, of blendstocks, and of finished petroleum products. The broader definition of oil inventories ensures that shifts in the storage demand for refined product are attributed to storage demand rather than flow demand shocks. Because the total change in oil inventories is a measure of production relative to consumption, it is often referred to as the market balance.

Implementing a Structural Model of the Global Oil Market

We estimate a structural vector autoregressive (SVAR) model of production, consumption and the real price of crude oil. The model is implemented with quarterly data from 1988Q1 to 2017Q3. The structural shocks are identified with sign restriction that reflect the economic intuition provided in existing studies.[3] Flow demand shocks are shocks that move prices and production and consumption in the same direction. For example, stronger economic growth might increase the flow consumption of fuels, which ultimately shifts the demand for oil and increases prices, and thus incentivizes higher production. Oil supply shocks are shocks that move prices in the opposite direction than production and consumption. For example, geopolitical events might compromise the flow oil production and thereby lead to a run up of global oil prices. Such price increases, in turn, would negatively affect oil consumption through the price elasticity of fuel demand. Finally, prices and quantities could also be affected by shocks to storage demand, which typically arise from changes in market participants' expectations or uncertainty about future demand relative to future supply.[4] Unlike flow demand and supply shocks, storage demand shocks move oil production and consumption in opposite directions.

Sign-identification of SVAR models does not provide a unique model estimate, but rather an entire set of admissible models. We provide a description of all models or selected quantiles to characterize the uncertainty surrounding our estimates. In the comprehensive paper, we also document that impulse responses of a unique structural model that is derived from insights of the relative persistence of the price impacts of demand and supply shocks closely resemble the median impulse responses of all admissible models.

Figure 1
Cumulative Effect of Different Shocks on the Real Price of Oil for All Admissible Models



Note: The vertical bars indicate major events in oil markets, notably the outbreak of the Persian Gulf War in 1990Q3, the onset of the Asian Crisis in 1997Q4, the Financial Crisis in 2008Q3, and the beginning of the 2014-2015 oil price drop in 2014Q3. The dashed lines indicate the pointwise 0.16 and 0.84 quantiles. The estimates take into account both estimation and model uncertainty.

What Drives Fluctuations in Prices and Quantities in the Global Oil Market?

Our results suggest that, on average, shifts in global fuel demand have been the most important driver of oil price fluctuations and explain much of the boom and bust cycles over the last decade (Figure 1). Flow supply shocks have also played a crucial role in many episodes, in particular during the 2014-2015 oil price decline. We also find that shifts in fuel flow demand have also accounted for most of the short- and medium-term variation in global fuel consumption while much of the lower-frequency movements in consumption can be traced back to oil supply shocks. Thus, the estimates suggest that stagnant oil supply during the 2000s were a drag on fuel consumption growth while the oil supply shocks in 2014 and 2015 provided a significant boost to consumption.

Estimates of Key Structural Parameters

Our framework also provides new estimates of the global oil supply and demand elasticity. Consistent with existing micro- and macro-evidence, the short-run oil supply elasticity is estimated to be around 1.5 percent. A particularly interesting result is that, in the short-run, the global fuel consumption appears to be similarly inelastic with respect to global crude oil prices. The median short-run demand elasticity in response to oil supply shocks is -2 percent, which indicates that a 10 percent price increase caused by a shortfall in oil supply would reduce global oil consumption by merely 0.2 percent within the same quarter. This result is startling because existing models of the global oil market suggest that global crude oil demand is considerable more elastic with respect to crude oil prices.[5] Likewise, studies investigating the reaction of local fuel consumption to changes in local fuel prices have documented fuel demand elasticities of the order of -30 percent.[6]

How can this apparent discrepancy be resolved? In the comprehensive paper, we use gasoline and diesel prices from 21 countries and document that there is an imperfect pass-through from global crude prices to local fuel prices. On average, a 10 percent increase in global crude oil prices is associated with a 50-60 percent increase in gasoline and diesel prices in the U.S. But this pass-through is much lower for all other countries, and for some even close to zero. This means that a low global fuel demand elasticity is not necessarily inconsistent with a higher global crude oil demand elasticity – which measures the reaction to refinery crude oil intake rather than fuel consumption – and a higher local fuel demand elasticity – which measures the reaction to local rather than global prices.

Implications

Information on global fuel consumption can be used to provide new insights on the global oil market and its relationship with the global economy. Our proposed framework is also useful for forecast scenarios, in particular when the underlying scenario is based on an explicit specification of the volume of oil consumption. This complements existing frameworks that rely on measures of real economic activity indicators to compare alternative scenarios of future oil demand.[7]

We also provide new estimates of key structural parameters in the oil market, which is important for two reasons. First, these parameters govern the evolution of prices and quantities in the global oil market, and are key to disentangling the various forces acting upon the oil market.[8] Second, they shed light on the effectiveness of global environmental policies. *Ceteris paribus*, a lower global demand elasticity implies that larger changes in global taxes or subsidies would be needed to affect fuel consumption, and that a larger fraction of the associated tax incidence would fall on consumers, refiners, or distributors as opposed to oil producers.

Finally, our results also show that it is important to distinguish between global elasticities and local elasticities. Models of the global oil market often rely on micro- or cross-country-estimates of the local elasticity to provide the bounds or priors for global elasticities that identify structural parameters.

When global and local elasticities are very different, this practice can distort the estimation and inference in such models.

Endnotes

1 See the International Energy Agency's *Oil Market Report* and *World Energy Outlook*, the Organization of the Petroleum Exporting Countries' *World Oil Outlook*, or the *BP Statistical Review of World Energy*.

2 Bilgin and Ellwanger (2017).

3 See, e.g., Kilian and Murphy (2012).

4 Kilian and Murphy (2014).

5 Kilian and Murphy (2014) and Baumeister and Hamilton (forthcoming).

6 Coglianese *et al.* (2016) and Levin *et al.* (2017).

7 See, e.g., Baumeister and Kilian (2014).

8 See, e.g., Knittel and Pindyck (2016).

The views expressed in this article are those of the authors and no responsibility for them should be attributed to the Bank of Canada.

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Weather Fear Premia Trades: An Update

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Ms. Hilary Till, the Contributing Editor of the G*lobal Commodities Applied Research Digest* (*GCARD*), presenting at the J.P. Morgan Center for Commodities' Advisory Council meeting.

Introduction

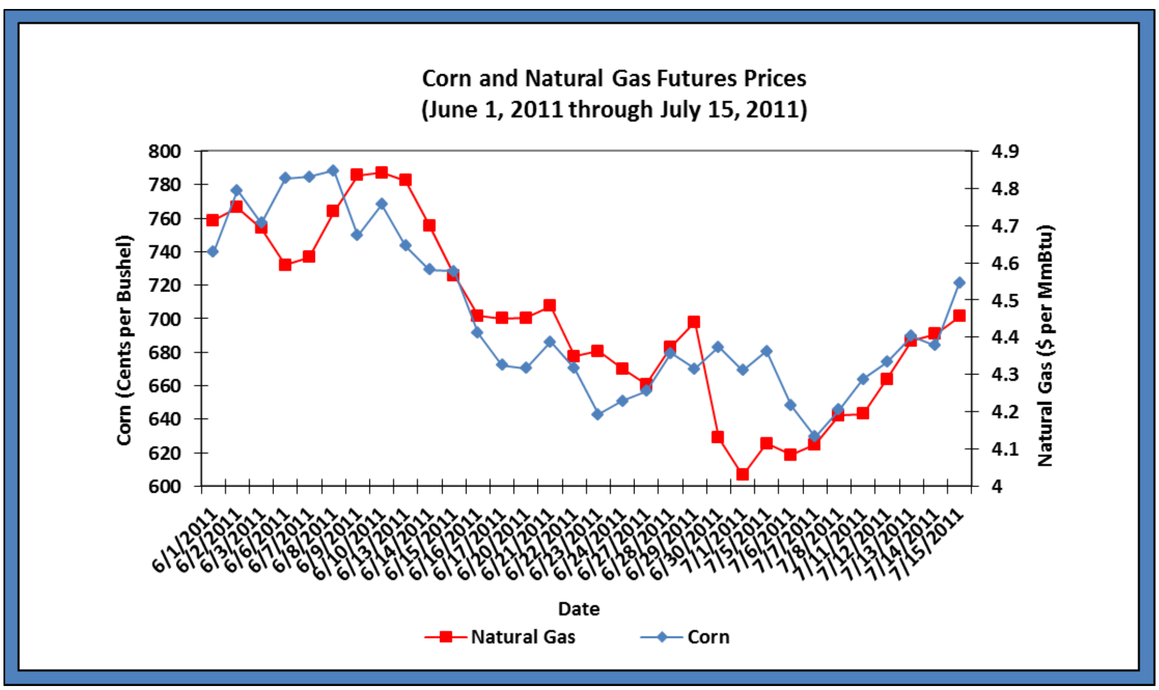
In this article, we will review a class of trading strategies known as "weather fear premia" trades. We will describe them, arguing that they may comprise a type of risk premium and noting the extra diligence needed in their risk management. We note that both superior trade construction and an analysis of fundamentals are also critical for the successful implementation of these types of trades. We conclude with a cautionary note on a catastrophic trading blow-up that occurred in November 2018, illustrating the risk of such strategies.

Description of Weather Fear Premia Trades

In Till and Eagleeye (2006), we described "weather fear premia" strategies. This early work noted that there were slight statistical edges in shorting certain futures contracts whose futures prices had built-in "weather fear premia" that would later subside if feared, but rare, weather events did not occur. For this class of trades, a futures price is systematically too high, reflecting the uncertainty of an upcoming weather event. We say the price is too high when an analysis of historical data shows that it is generally profitable to be *short* the commodity futures contract during the relevant time period. And further that the systematic profits from the strategy are sufficiently high that they compensate for the infrequent large losses that occur when the feared, extreme weather event does in fact occur. In practice, futures traders do not take advantage of these opportunities by passively shorting a market; instead they exploit these slight statistical edges (a) through alternative trade constructions such as through futures calendar spreads in order to improve the return-to-risk of such strategies, and (b) only after taking into consideration a commodity market's fundamental picture.

These trades can be found in the tropical, grain, and natural gas futures markets. Some of the relevant timeframes for these trades include the onset of the Brazilian winter and summer-time in the U.S. Midwest. In the case of the Brazilian winter, an extreme frost can damage Brazil's coffee trees. In the case of the U.S. summer-time, an exceptional heat-wave can impair corn pollination prospects as well as stress the delivery of adequate natural gas supplies for peak air-conditioning demand. Given that corn and natural gas trades are heavily dependent on the outcome of weather in the U.S. Midwest, their prices can wax and wane at similar times during the summer. Figure 1 illustrates how both corn and natural gas prices had common reactions to the possibility of extreme heat in 2011.

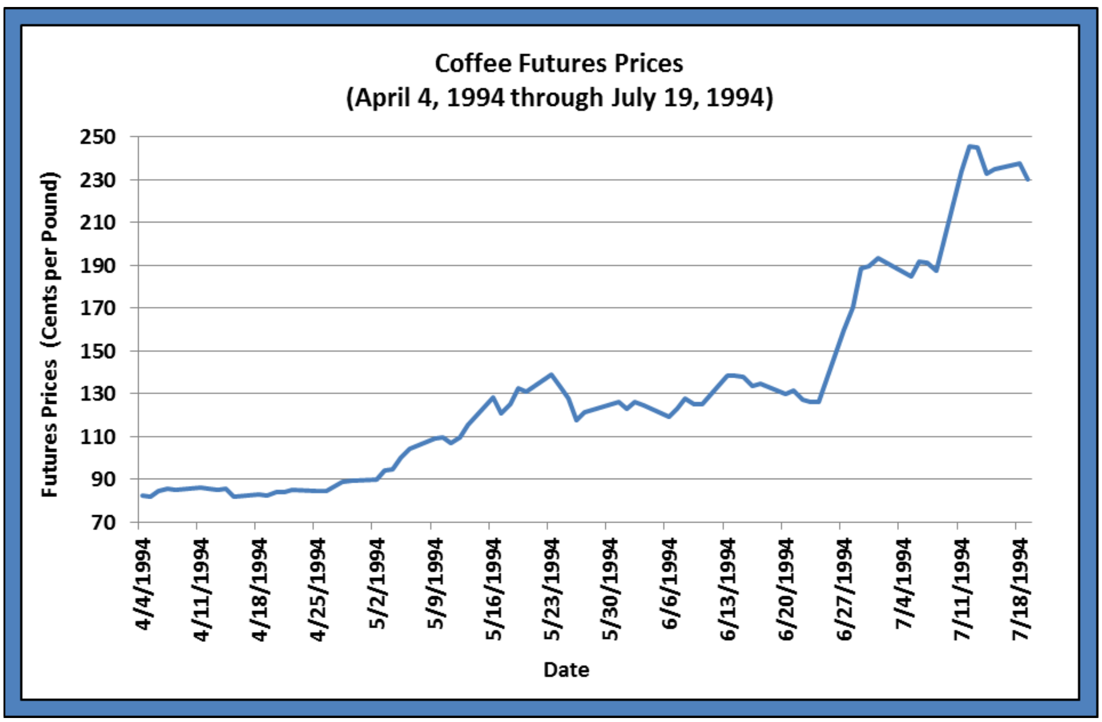
Figure 1
Corn and Natural Gas Futures Prices during the Summer of 2011, Exhibiting Common Reactions to the Prospect of Extreme Heat



Source: Till (2016), Figure 3.

Till (2008) further described these opportunities as having short-option-like payoff profiles. While over long periods of time it has been profitable to be short weather-sensitive commodity markets around the time of their (respective) maximum weather uncertainty, these strategies can have very large one-off losses, which create classic short-option-like profiles. Therefore, such strategies should only be a fraction of one's portfolio. For example, Figure 2 illustrates the risk of a *short* position in coffee if such a position were held during the Southern Hemisphere winter; in 1994 consecutive bouts of extreme weather did occur, as described by the derivatives trader, James Cordier, in an article entitled, "My Best Trade," regarding profitably taking on *long* positions in this market (Cordier, 2005). Further in Neal (2008), Cordier stated, "The most memorable trade has to be long the coffee market in 1994. … [F]orecasts called for a very cold winter for the southern growing regions of Brazil. Sure enough, freezing temp[erature]s invaded coffee fields not once but twice that year and prices tripled in a very short period of time. (Brazil's coffee region has since migrated north.)"

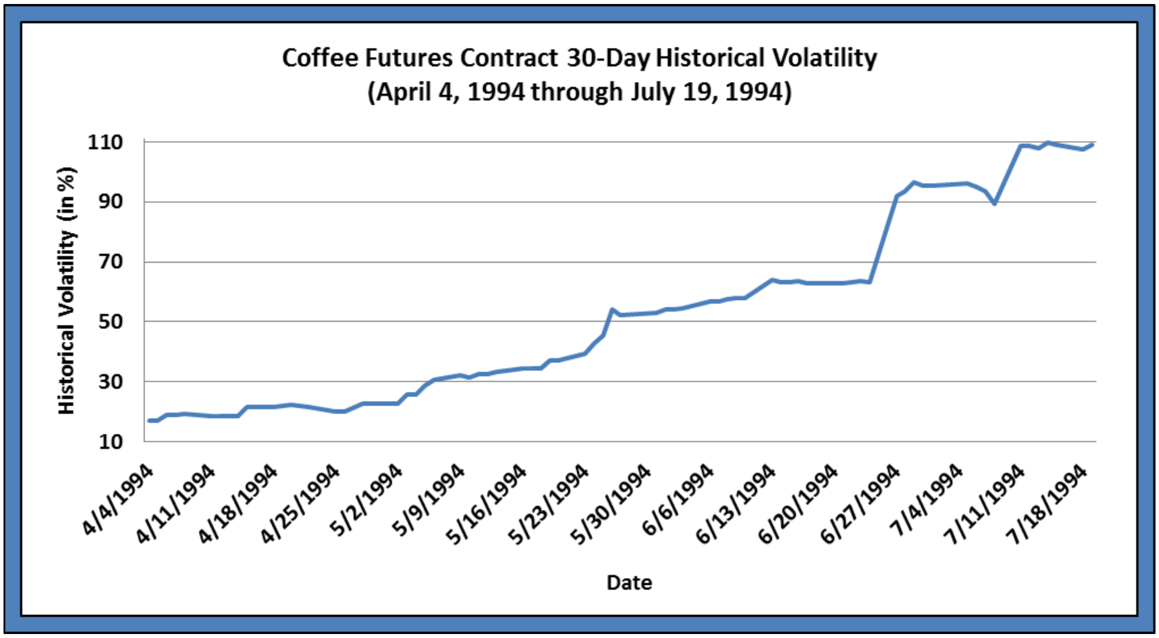
Figure 2
Coffee Futures Prices during Extreme Brazilian Winter



Source: Till and Eagleeye (2006), Exhibit 6-5.

Figure 3 on the next page further demonstrates how explosive the price change in coffee was during this time of unusual weather by showing the evolution of three-month historical volatility in this market.

Figure 3
Explosive Volatility in Coffee Futures Prices during Extreme Brazilian Winter



Source: Premia Research LLC.

A Type of Risk Premium

Chang (1985) defined the term, "risk premium," as follows: this premium "generally refers to an average reward to investors for being willing to assume a risk position in a risk-averse financial world. The reward in this form should not be conditioned on any superior judgment or inside information." Perhaps weather "fear" premia comprise a type of risk premium. Cochrane (2001) provided one possible explanation for why weather premia may exist in some commodity futures markets:

> In really perfect capital markets, there should be no weather premium. Weather is pretty much a beta-zero risk relative to the rest of the market – there is no correlation between the weather and the S&P 500. … Thus, investors should be willing to provide this weather insurance for a very small premium. But they don't. It seems … pretty analogous to the catastrophe insurance market. Catastrophe reinsurance itself, and the catastrophe enhanced bonds, have given quite high returns despite a zero beta risk. My own interpretation is that markets are quite a bit segmented.

Now the issue with all risk-premia strategies across asset classes is that they require active management. Whatever the asset class, a manager must decide how much to leverage the strategy, how many reserves to set aside in the event of a catastrophic event, and whether to give up any returns by hedging out some of the strategy's extreme risks. This is analogous to the issues facing both commercial banks and insurance companies.

Active Management

As in all strategies that exploit structural phenomena, one can certainly choose to passively invest in weather-premium trades, expecting to earn a positive return over long periods of time. Alternatively, one can also create quantitative models, incorporating fundamental and technical data, so that one can judge if weather-sensitive futures contracts are especially overvalued, if at all, in a particular year. One would certainly do this in an actively managed commodity futures program. And in fact, hedge fund managers and asset managers alike have a higher expectation for trades and investments than merely earning a risk premium (Till, 2017). An actively managed position should have superior (entry-and-exit) timing, careful trade construction, and disciplined risk management rules and should not just passively involve entering into a trade that has a statistical expectation of profit.

Inventories are a crucial fundamental variable in the commodity markets and especially in weather-sensitive markets. If there is too little of a commodity, then that means there are inadequate inventories and therefore the only lever available to balance supply and demand is price, which must correspondingly increase. The inability of "the market as a whole to carry negative inventories," as Deaton and Laroque (1992) explained, causes commodity markets to be prone to violent price spikes.

<u>Corn</u>

The Hightower Report (2002) described how to evaluate the corn futures market during the summer by evaluating both the inventory and technical positioning in the market:

> July weather will be critical to [corn] yield potential. … Given the tightness in world [inventory] numbers and the fact that speculators were still holding a net short position of over 28,000 contracts in the last Commitments-of-Traders Report with Options (as of June 4th) [along with] the threat of a significant reduction in yields (if hot and dry weather emerges in July), the upside potential in the market is explosive.

<u>Natural Gas</u>

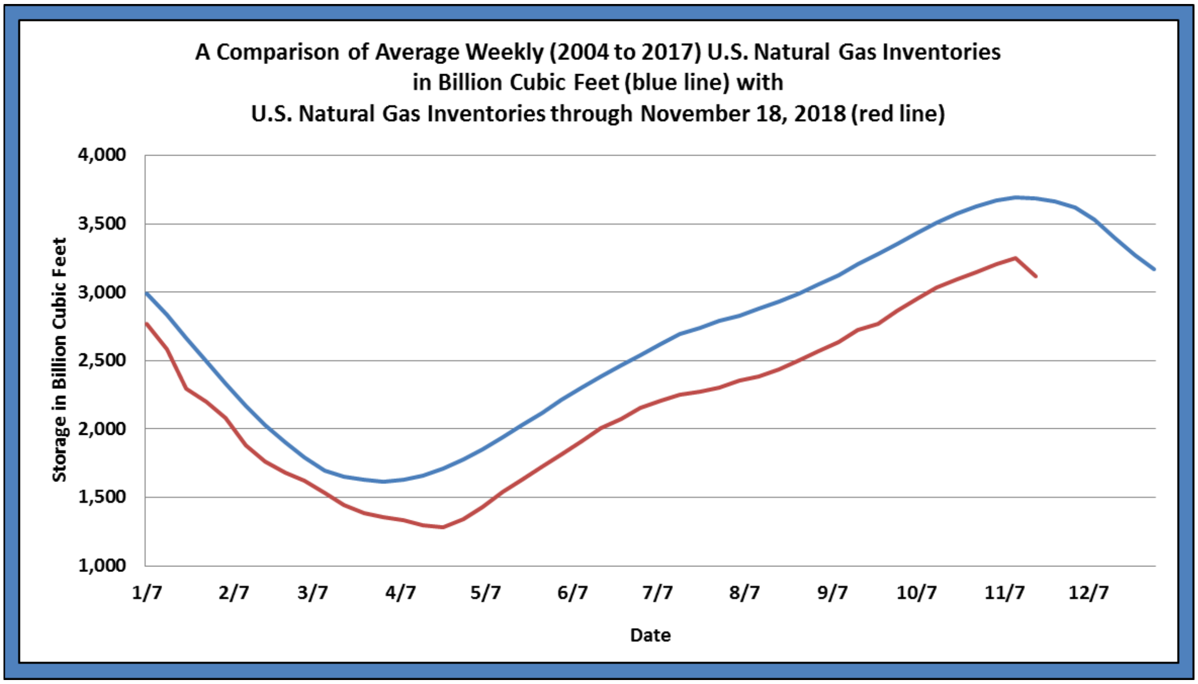
Natural gas prices are also subject to the influence of its inventory situation, combined with weather outcomes (whether it is the potential of summer heatwaves or winter freezes.) *Dow Jones* (2005) reported how at the beginning of January 2005:

> Natural gas futures prices on the New York Mercantile Exchange … [experienced] a 5.8% drop as traders pointed to the confluence of near-record storage surpluses and increasingly mild temperature expectations as the source of the market's weakness. … "It's going to just erase the whole winter premium because there's no weather threat at all," said … [a futures broker].

In mid-November 2018, Pirrong (2018a) warned against fading weather in the natural gas futures markets, after examining this market's inventory situation. He particularly warned against taking bearish positions in a type of natural gas futures calendar spread known as the "widowmaker": "[T]he storage build in 2018 was well below historical averages ... Add in a dash of cold weather, and the widowmaker is back …"

Figure 4 illustrates Pirrong's fundamental observation.

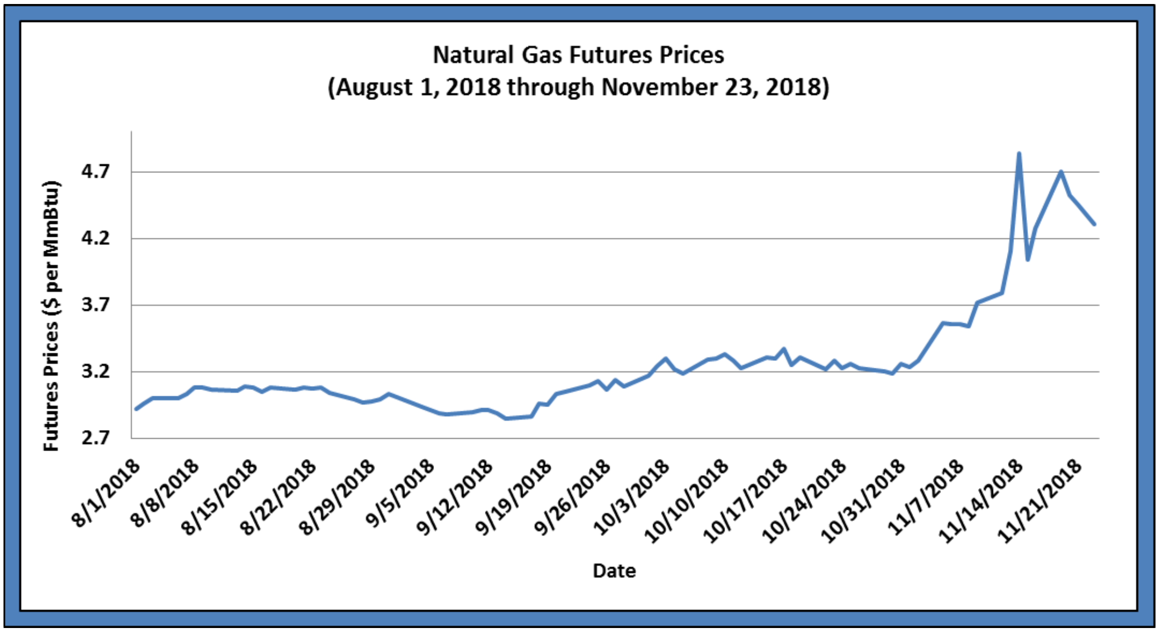
Figure 4
U.S. Natural Gas Storage Builds in 2018 (through mid-November) were Below Average



Source: Premia Research LLC.

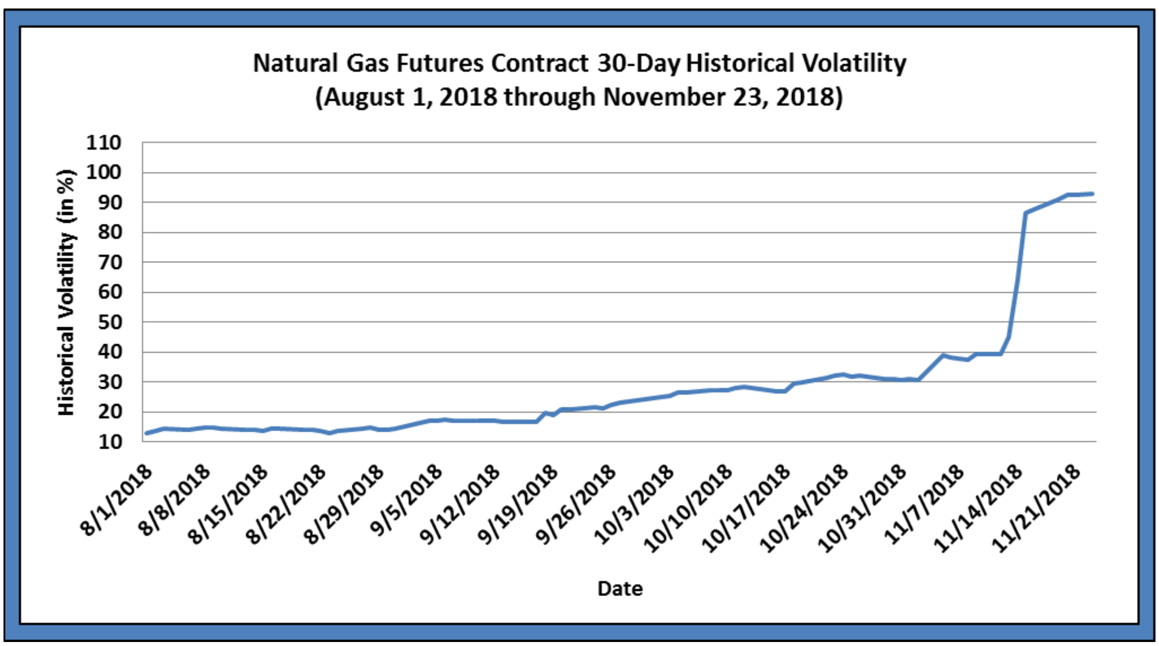
And in fact, a cold snap did occur in mid-November 2018, sending natural gas futures prices and volatility spiraling upward, as shown on the next page in Figures 5 and 6 respectively.

Figure 5
Natural Gas Futures Prices during a Cold Snap



Source: Premia Research LLC.

Figure 6
Explosive Volatility in Natural Gas Futures Prices during a Cold Snap



Source: Premia Research LLC.

The alert reader will note the similarities between the volatility graph for coffee in Figure 3 and the volatility graph for natural gas in Figure 6, indicating that natural gas' bout of volatility in November 2018 is not unprecedented for experienced traders specializing in weather-sensitive commodity futures markets.

Risk Management Case Study

Till (2008) described how natural gas seems to be at the center of a lot of trading debacles. Natural gas derivatives trading has offered hedge funds a potentially alluring combination of scalability and volatility, and also at times, pockets of predictability. This faith has continued unabated. Even in the aftermath of Amaranth sustaining the largest hedge-fund loss thus far in history in 2006, one of Amaranth's natural gas traders based in London was soon able to obtain a $1-million signing bonus when joining another large-scale global macro hedge fund, according to Harris (2006). Further, by the spring of 2007, Amaranth's former head natural gas trader had apparently obtained close to $1-billion in investor commitments for a new hedge fund headquartered in Calgary, Alberta, reported Herbst-Bayliss (2007). That said, a July 2007 U.S. regulatory action against the head trader himself (and not just against his former employer, Amaranth) appeared to put an end to these plans.

<u>"Have I Lost All the Money in My Account Then?" Answer: "Yes"</u>

What is the latest trading blow-up in the natural gas futures markets? According to press reports, James Cordier's Commodity Trading Advisor firm, OptionSellers.com, sustained catastrophic losses in November 2018 in the volatile energy markets, including in natural gas. Noted Banerji (2018), "A 2015 marketing document from OptionSellers.com reviewed by the *Wall Street Journal* encourage[d] investors to add option selling to their retirement strategies."

In the Yale University working paper by Goetzmann *et al.* (2002), the authors had warned investors about such strategies. The Yale professors show that "expected returns being held constant, high Sharpe ratio strategies are, by definition, strategies that generate modest profits punctuated by occasional crashes." As summarized in Till (2002), the experience of the Art Institute of Chicago's endowment provided evidence for the Yale professors' concern. One of the endowment's hedge fund managers noted in their marketing material that their fund had "the highest Sharpe ratio in the industry," according to Dugan *et al.* (2002). The hedge fund noted it would combine "cash holdings with stocks and riskier index options" in such a way that they "could guarantee profits of 1% to 2% a month in flat or rising markets. The fund … could lose money only if the stocks to which the options were tied dropped more than 30%." This firm's funds were wiped out in late 2001. Unfortunately, as will be covered, apparently OptionSeller.com's investors sustained a worst result even than this.

Banerji (2018) explained that OptionSellers.com "specialized in selling options contracts to collect income …" The firm was forced to liquidate its positions in mid-November "following wrong-way options bets on oil and natural gas prices." In an email to a client, "OptionSellers.com listed answers to frequently asked questions, including, 'Have I lost all the money in my account, then?' The answer given: 'Yes.'" Further, "[s]ome clients were left with a negative balance, meaning they are in debt to …

OptionSeller.com's clearing firm …" The firm had 290 clients. According to one estimate in Malik *et al.* (2018), the "losses from the failure of the [strategy] … could exceed $150 million."

Banerji (2018) further quoted from a client email sent by OptionSellers.com:

> "Your account was caught in an extraordinary bout of volatility in the energy markets. In particular, natural gas prices experienced a parabolic move over the past 3 trading sessions. We had a short call position here that was on the wrong side of this. The magnitude of this move was so fast and intense that it overwhelmed all risk measures in place. It was like nothing we've ever seen."

The final sentence of this explanation was not an obvious statement to make, given the principal's past success in trading a market beset by extreme weather conditions: specifically, the coffee market during the Brazilian winter of 1994.

The founder of OptionSellers.com also referred to the market's price action as a "rogue wave." Pirrong (2018b) explained why he found this characterization unconvincing:

> [T]he natural gas market was primed for a violent move: low inventories going into the heating season made the market vulnerable to a cold snap, which duly materialized and sent the market hurtling upwards. The low pressure system was clearly visible on the map, and the risk of big waves was clear …

In addition to Pirrong's fundamental analysis of the natural gas markets, one might also point out that "dramatic swings in implied volatility … are [actually] inherent to the natural gas options market," whereby this market's implied volatilities periodically breach 90% (Till, 2008).

Pirrong (2018b) provided the following cautionary note to commodity investors: "Selling options is effectively selling insurance against large price moves. You are rewarded a risk premium, but this isn't free money. It is the reward for suffering large losses periodically."

Conclusion

We would conclude that if an investor decides to allocate to short options (or short options like) strategies such as weather fear premia trades, there are two lessons to keep in mind: (a) one should not employ a trade construction that has potentially unlimited losses; and (b) given the rare, but catastrophic, event risk inherent to such strategies that only a modest fraction of one's portfolio should be devoted to these trades.

Endnotes

Ms. Hilary Till presented this paper at UBS' "When Risk Premia Returns" conference, which was held at the New York Stock Exchange on February 4, 2019.

It should be added that this article is provided for educational purposes only and should not be construed as investment advice or an offer or solicitation to buy or sell securities or other financial instruments. The information contained in this article has been assembled from sources believed to be reliable, but is not guaranteed by its author. Any (inadvertent) errors and omissions are the responsibility of Ms. Till alone.

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A Mean-Variance Approach for Optimizing Physical Commodity Production Decisions

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Introduction

In general, processors aim to maximize their profit by operating up to the point where their marginal cost equals their marginal revenue. This is challenging to do when supply and demand are volatile, which is a dynamic often observed in commodity markets. Common optimization planning models can address these scenarios by forecasting sales prices and customer demand, then running iterative algorithms over the data to generate the production plan that maximizes profit at a point in time. However, these production plans can be highly reactive as product price forecasts and other inputs change. This paper examines an approach to optimizing physical production decisions ("make") that considers risk, specifically in situations where:

1. The processor/refiner converts one raw input into many output combinations. For example, milk gets turned into a set of products, such as a combination of cheese and whey protein;

2. The processor is constrained by the supply of the raw input. These constraints could arise from geographic supply limitations, regulation, or agreements with suppliers;

3. The processor has plant capacity limitations and cannot convert the raw input into only one product-mix (that is, some undesirable products may need to be made due to the location/availability of physical refining assets);

4. Processors may be forced to make certain products, regardless of their margins, due to contracts with customers; or

5. Processors make products that either cannot be hedged or that do not have an appropriate liquid hedging instrument.

This report investigates an alternative approach to optimizing make using mean-variance analysis. Markowitz's mean-variance analysis is a well-known method for asset portfolio optimization that considers both risk and return (Markowitz, 1952). By applying this framework, an alternative approach to commonly used optimization planning models is taken. It is hypothesized that the advantages in this framework are a more consistent make over the long term and less volatile returns. The following sections discuss a method for adapting the Markowitz theorem to a constrained processor situation where the processor takes a raw input and has the option to refine it into many products, and finally an example is presented.

Method

Markowitz's mean-variance analysis provides the portfolio weightings, $\mathrm{w_i}$, for asset, i, that maximize the expected excess return per unit of standard deviation. These weightings are calculated from the returns, $\mathrm{R_i}$, and covariance, $\rho_{\mathrm{i,j}}$, of assets i and j. In this application i and j are streams and $\mathrm{R_i}$ is the expected average return of the stream, i. Absent any constraints, one unit of raw input collected by a commodity processor can be transformed into any stream of products. Consider a stream as the set of products made by a recursive procedure utilizing the raw input and the subsequent by-products of production. As an example, when skim milk is extracted from raw milk, a fat-concentrated liquid remains. From this, the fat can be extracted and butter produced, leaving butter milk as the remaining by-product. Therefore, an example of a stream is: $i = \{skim\ milk, butter, butter\ milk\}$.

The value of a stream can be calculated at any point in time. This value is the sum of the yield-weighted prices of all component products in the stream minus their yield-weighted marginal production costs. Return, $\mathrm{R_i}$, is the percentage change in value of the stream from period $t-1$ to period t, which is shown in the equation below:

$$\mathrm{R_i} = \sum_k \alpha_{i,k} \frac{(P_{k,t}-C_{k,t})-(P_{k,t-1}-C_{k,t-1})}{(P_{k,t-1}-C_{k,t-1})}$$

where $\mathrm{P_{k,t}}$ is the price of the commodity, $k \in i$ at time t, and $C_{k,t}$ is the variable production cost of k at time t. $\alpha_{i,k}$ is a yield coefficient, $k \in i$, such that if the processor takes one unit of the raw input they will make $\alpha_{i,k}$ units of the commodity k. Likewise, in this scenario $\rho_{\mathrm{i,j}}$ becomes the covariance between the returns of streams i and j. Next, the processor's constraints are discussed.

If the processor operates in a commodity where the refined products do not have a liquid financial market or if the processor does not have access to the financial markets then the solution is constrained to have weightings $\mathrm{w_i} \geq 0$ for each stream, i. This is important as the Markowitz optimal portfolio may suggest that the processor should short some streams.

Processors also have capacity and production constraints. Capacity restrictions, such as physical refining limitations, are likely to cause minimum and maximum output constraints for certain products. Production constraints may force the processor to make some products regardless of whether this is optimal in the mean-variance sense. The minimum make, m_k, and maximum make, M_k, are dependent on the unique situation of a given processor. That is, the make v_k , $m_k \leq v_k \leq M_k$. For example, supply agreements may force the make of the downstream product k to be greater or equal to some minimum make, m_k; and plant capacity constraints may force the make of k to be less than or equal to some maximum make, M_k.

Once the relevant constraints have been established the optimal portfolio can be computed using an optimizer such as the Excel Solver. The optimizer would assign a portion of the total raw input, U, to the streams. The make of product k in a stream i is,

$$v_{k,i} = U\beta_i \, \alpha_{i,k}.$$

where β_i is the proportion of raw input assigned to stream i such that $1 = \sum_i \beta_i$ (that is 100% of the raw input is assigned to a stream.) It follows that the total make across all streams is, $v_k = \sum_i v_{i,k}$, which must be within the make constraints.

The optimizer must allocate the constrained raw input across the streams such that it maximizes the Sharpe ratio. It is important to note that β_i is not analogous to the asset weightings in mean-variance analysis. In this framework, the weights, w_i, represent the proportion of the total revenue that is expected to come from each stream,

$$w_i = {\sum_k P_k v_{i,k}} \Big/ {\sum_k P_k, v_k}$$

$$\mu = \boldsymbol{w}^T \boldsymbol{R},$$

$$\sigma^2 = \boldsymbol{w}^T \boldsymbol{\rho}\, \boldsymbol{w},$$

$$\text{Sharpe ratio} = \frac{\mu - r}{\sigma},$$

where $\boldsymbol{w}$ is the vector of weights, $\boldsymbol{R}$ is the vector of returns, $\boldsymbol{\rho}$ is the stream covariance matrix, and r is the risk-free rate.

An Example: Applying This Method to a Lifelike Dairy Company

Figure 1
Sample Yield Table Applied in Dairy Processor Example

	kg of product per kg of base product processed				
Base Product	**Butter**	**Butter Milk Powder**	**Whey Protein Concentrate**	**AMF/Ghee**	**Lactose**
Whole Milk Powder	0.03				-0.04
Skim Milk Powder	0.44	0.01			-0.08
Cheese-Dry Salted		0.09	0.02	0.01	0.27
Casein	1.58	0.03	0.03		0.25
MPC 70	0.96	0.01			0.98

The above yield table was derived using data from Sneddon *et al.* (2015) and Bylund (2003). Using an extended version of this table, a historical time series of stream values was calculated with the time period of the underlying proprietary price series running from July 2005 through July 2017. The period-to-period percentage change in these stream values was taken as the return time series to be used in Markowitz's mean-variance framework, $\mathrm{R_i}$, and the annual variance-covariance matrix between streams was calculated.

In the optimal case no further constraints would be applied from this point onward. For a set of product prices chosen by the processor, the model would calculate the weight in each stream required to get the processor to the tangency portfolio (the orange point in the chart in Figure 2 on the next page) where the Sharpe Ratio is maximised. When the model was run with only a raw input constraint and no make constraints, a Sharpe ratio of 0.63967 was achieved. This is 0.10% below the theoretically optimal Sharpe ratio of 0.64034. It should also be noted that this solution involved shorting some products.

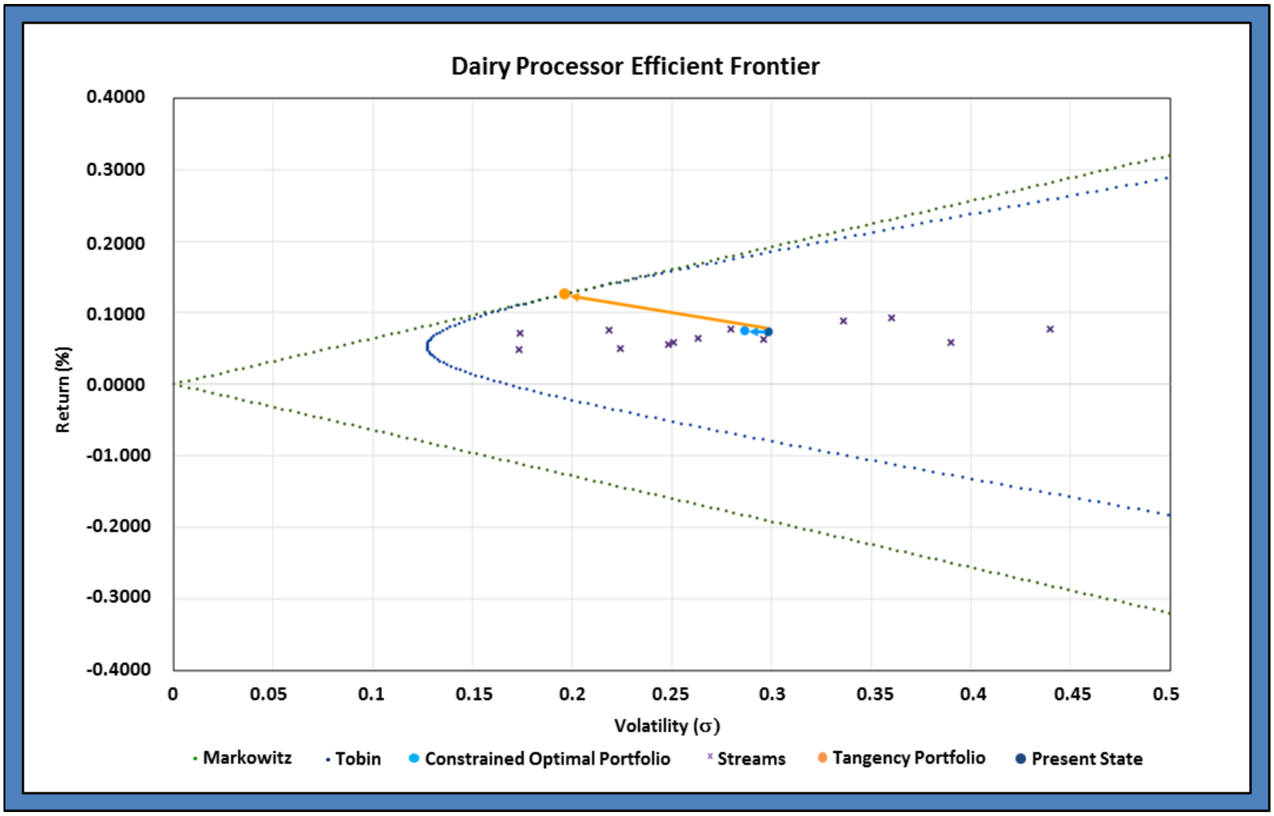
Setting Up the Minimum and Maximum "Forced Make" Production Constraints

The upper production constraints, M_k, for each product were estimated by, $\widehat{M}_k$, using the historical maximum production for each product in a given month scaled up by 10%. This upper bound is theoretically less than the maximum refining capacity of the dairy company. However, this estimation was used because milk refining is geographically constrained and therefore the maximum refining capacity is not a realistic upper bound.

The lower bound, $\widehat{m}_k$, assumed no forward sales contracts and estimated the minimum make under the assumption that milk was geographically constrained. It is assumed that all products had infinite demand, the prices of all alternative products were at their 95th percentile, and that milk collections were 15% below forecast. In other words, the forced make of an undesirable product in a year where milk solids collected were low was considered.

To calculate the constrained optimal portfolio (the blue point in the chart in Figure 2), Excel's GRG Nonlinear Solver was used. The Solver was set to find the make, v_k, of each product that led to the set of weights, $\mathrm{w_i}$, which maximized the Sharpe ratio of the portfolio with the constraint $\widehat{m}_k \leq v_k \leq \widehat{M}_k$ applied. This procedure was run several times and with varying initial criteria and mutation rates; each run resulted in the same optimal output.

Figure 2
Efficient Frontier Output as Applied to a Dairy Processor



Conclusion

This paper presents a risk aware framework for physical production planning for a commodity processor that steps away from traditional optimization approaches. This approach treats production decisions as analogous to a fund manager's asset selections where the processor's universe of assets is the streams of products that it can make. By applying mean-variance analysis it is expected that a processor will be more fairly rewarded for the risk implicit in their production plan.

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U.S. Natural Gas Meets the Global LNG Market – A Potential to Reshape the NYMEX Natural Gas Term Structure

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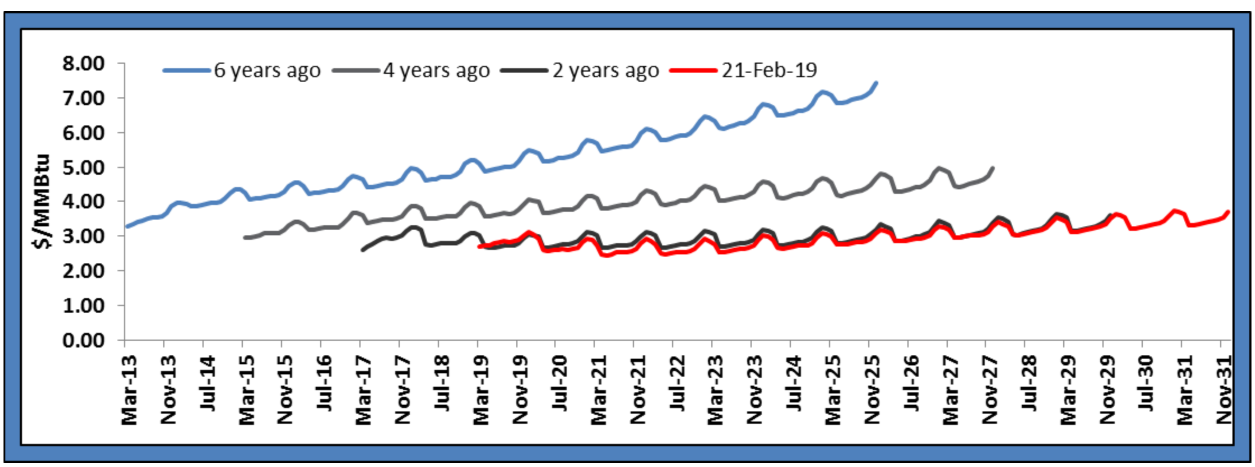
Over the past decade, it is unmistakable that the dominant narrative for the U.S. natural gas market has been the shale gas renaissance and the subsequent abundance of production growth. Rampant production growth has redefined the very characteristics that once were the U.S. natural gas market: volatility, seasonality, and an overall higher range of price – to name a few. As a result of this nearly decade-long production growth story, the average annual price for U.S. natural gas has fallen dramatically, eroding along with it all those familiar characteristics.

Market participant behavior evolved as production overwhelmed the balance, changing the very shape of the New York Mercantile Exchange (NYMEX) natural gas forward curve. While historically producer hedging was balanced by consumer hedging and investor interest in deferred-tenor length, the constant roll down of price appeared to dissuade consumer hedging. As supply sources became plentiful, consumers reduced hedging tenors, at times eliminating entire hedge programs as natural gas price volatility to the upside nearly disappeared. At the same time, the upstream community – overwhelmed with molecules – found itself hedging further and further along the forward curve to capture higher prices as increased technological drilling efficiencies reduced production costs.

An extremely lopsided flow dynamic in the contracts traded within the U.S. natural gas market began to emerge – with incredible selling pressure exerted on the deferred portion of the forward curve from producer hedging. As a result, the contango of the NYMEX forward curve that once highlighted upside price risk for the U.S. natural gas market nearly disappeared; please see Figure 1.

Figure 1
NYMEX Natural Gas Forward Curve Over Time



Sources: NYMEX, Bloomberg, JPMorgan Commodities Research

Never more has this supply-side narrative been supported than during 2018 when annual production growth averaged ~8.5 Bcf/day over 2017 levels. And while we could review the technological advances and efficiency gains impacting the supply-side of the balance *ad nauseam*, what we found the most intriguing about 2018 was the ability for the U.S. natural gas market to find some semblance of balance not only through weather, but more importantly through organic growth in demand – primarily in the exports market.

The evolution of the price decline that persisted for the better part of the past decade clearly led to opportunities to find new demand outlets for U.S. natural gas molecules – be it through the shift in the domestic power generation sector from coal-to-natural gas as a primary fuel source, an increase in industrial demand given the economic advantage and stability of U.S. natural gas prices, or piquing the interest of gas-consuming countries abroad that rely on imports to satiate demand.

If 2018 is defined by exorbitant production growth, we would deem 2019 a year recognized for a meaningful step-change higher in U.S. liquefied natural gas (LNG) export capacity. The introduction of this chunky demand source to combat the overwhelming amount of production growth in the U.S. natural gas balance may be a start in the restoration of those long-lost characteristics.

A severely flattened forward curve, with near- to intermediate-term backwardation, has led to a series of shifts in the U.S. natural gas market. From a dearth of new storage capacity to a slowing of producer hedging, the current fundamental environment is primed for a structural shift in the forward curve as a new type of consumer participant is introduced to the U.S. natural gas balance – U.S. LNG consumers.

Lack of Increased Storage Capacity to Support Seasonal Volatility

With these substantial changes in supply and demand, a clear laggard in growth has been storage capacity. Since 2008, working gas storage capacity has grown ~572 Bcf through 2017 as reported by the U.S. Energy Information Administration (EIA), with only ~66 Bcf of that growth occurring from 2014 to 2017. It may appear odd that amid the substantial growth in supply, demand, gas processing plants, and natural gas pipelines over the past several years that storage growth has been stunted. However, it is the very shape of the forward curve which is the most likely cause for this slowdown in working gas storage capacity growth. The economic incentive to store has been stripped away from storage operators with the disappearance of the contango and seasonality in the NYMEX forward curve.

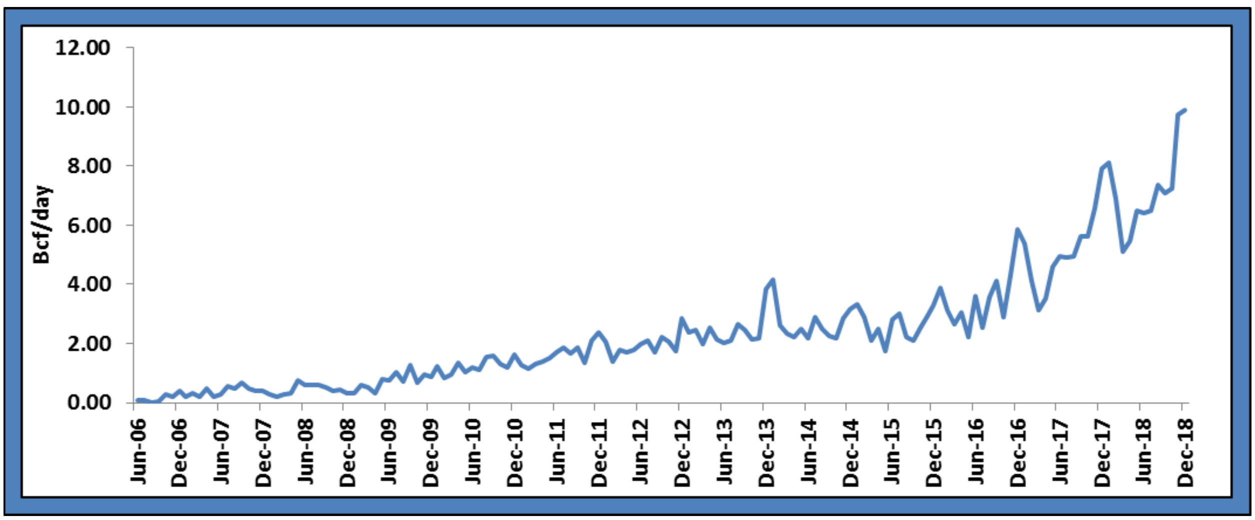
As a result, the extensive amount of gas production from Northeast wells, as well as from oil plays and the Haynesville Shale play will serve as a proxy for storage capacity.

The primary repercussion of a natural gas system becoming more reliant on a production site to meet demand is increased price volatility. The call on that production will likely manifest through regional pricing (rising to redirect flows to the necessary region and falling to push gas to other regions) with the NYMEX futures price also likely to participate.

One only has to look at the U.K. National Balancing Point (NBP) market for the implications of relying on imports from another region to meet demand, especially during the winter withdrawal season. With the decommissioning of the Rough storage facility, the main source to meet winter-related demand in England, volatility in the U.K. NBP price has been prevalent. During the summer period, NBP prices tend to dive lower, signaling there is too much gas on the grid with the inability to store the excess gas in this storage facility. However during the winter withdrawal period, the U.K. NBP price now rallies more significantly in order to meet additional demand through LNG imports. Essentially, Rough storage served as a price volatility dampener and with that dampener removed, the U.K. natural gas market is exposed to global pricing.

It would seem more insignificant if the global LNG market was well supplied, which one could argue at the current time that it is. However, the recent environmental changes in China – forcing industrial consumers of coal to switch to natural gas during the winter season – suggest that a structural change in demand may be upon the global LNG balance. The 2017-2018 winter was one example of this increased demand that sent LNG imports into China soaring above 8 Bcf/day. With less weather-related demand, Chinese imports of LNG still remained above 9 Bcf/day during the last two months of 2018; please see Figure 2.

Figure 2
Chinese LNG Imports



Sources: CGA, Bloomberg, JPMorgan Commodities Research

Deferred Producer Hedging Begins to Slow

One ramification of the steady barrage of producer hedging that has hammered the natural gas NYMEX curve nearly flat over the past decade is the fall in the absolute level of price. This has clearly corresponded with sizeable declines in production costs. One example can be seen from the likes of the Haynesville Shale play. In 2011 and 2012 when production from the region was in vogue, production costs for the play were cited as high as \$3.75/MMBtu. A resurgence of drilling in the play since 2017 has some producers touting the cost of production as low as \$2.25/MMBtu, with anecdotal data pointing to even lower costs.

Yet, with the emergence of crude oil shale production in the U.S., competition for the same drilling and completion resources has become increasingly apparent. Correspondingly, the upstream community has reported increased drilling and completion costs, especially as efficiency gains continue to diminish.

With lower absolute prices across the forward curve – at the time of this publication both calendar strip 2021 and 2022 prices hovered around $2.65/MMBtu, nearly 10¢ below the calendar 2020 strip price – there appears to be a slowing in producer hedging in the deferred tenors. The backwardation of the forward curve in the near- to intermediate-term optically makes it difficult to execute hedges when the curve implies a potential roll up in price should the current fundamental environment remain. Additionally, incorporating the regional basis to Henry Hub, regional fixed prices in Appalachia (the primary source of growth in U.S. natural gas production) have fallen closer to $2/MMBtu – a price level which appears to hold some producers captive.

Barring another major technological advancement, cost inflation is likely to set a soft floor in price for U.S. natural gas. We believe that a NYMEX calendar strip price around the $2.50/MMBtu level is likely to elicit a pause in hedging as the regional fixed price falls below $2/MMBtu. This is especially true as primarily gassy producers will have further competition from oil producers and the associated natural gas coming from liquids-rich plays.

Enhanced Volatility and Seasonality Makes a Return

While the U.S. market becomes more reliant on production from the wellhead to meet demand and the upstream community has bumped up against less appealing hedge prices, structural changes on the demand side of the balance has opened the U.S. natural gas market to economies, politics, and fundamental balances abroad. During 2019, we expect more than 3 Bcf/day of LNG export capacity growth. This growth has and is likely to continue to contribute to increased price volatility and seasonality for the U.S. natural gas market.

U.S. LNG exports first became meaningful to the domestic gas balance during the winter 2017-2018 season. Only ~2.4 Bcf/day of export capacity was officially available during the early part of the winter season; however, at times nearly ~3.2 Bcf/day flowed as feedgas into the one functional LNG export facility, Sabine Pass. That feedgas is essentially a representation of demand.

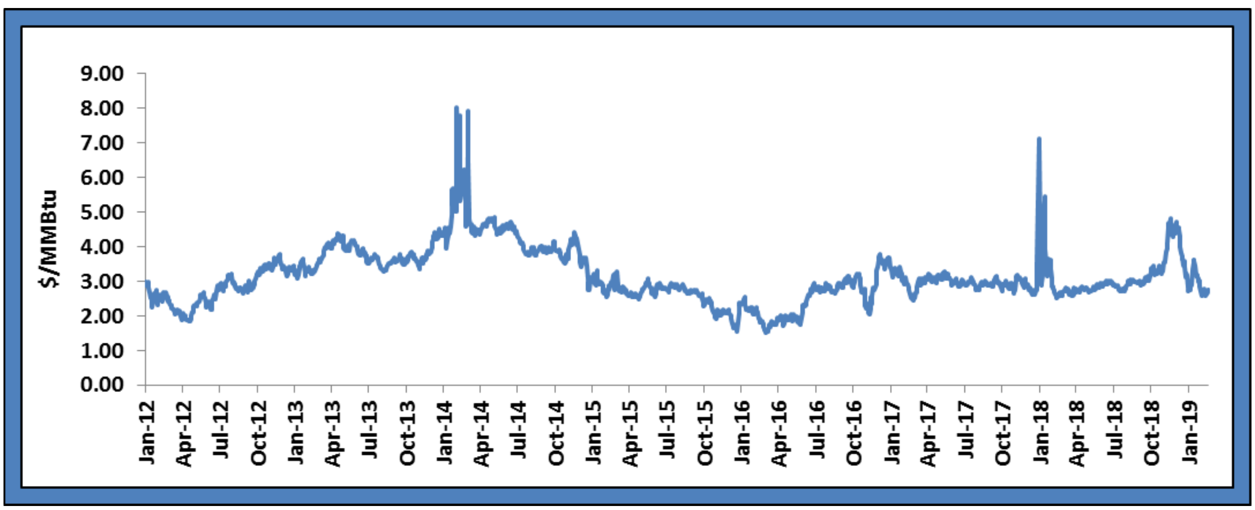
The meaningful pull of U.S. natural gas into Sabine Pass was the result of several non-U.S. based factors. Sources of domestic natural gas in Europe are dwindling. Despite, steady production levels from the North Sea, the aforementioned decommissioning of the Rough storage facility in the United Kingdom along with diminishing Dutch natural gas production has left Europe more heavily reliant on imports to meet weather-related demand. In Asia, China's stringent environmental policies, imposing winter bans on the use of coal-boilers by industrials, continue to support increased LNG demand.

Aside from the steady pull of U.S. natural gas into Mexico, this would be the first time that countries abroad had a direct impact on the U.S. gas balance in over a decade. Additionally, the pull of U.S. gas by these gas-consuming countries appeared somewhat impervious to price, as meeting weather-related demand was the priority. During that winter season, the day-ahead Henry Hub natural gas price rallied above $5/MMBtu twice – the first time these price spikes were observed since the polar vortex winter season of 2013-2014.

With an increase in LNG capacity during 2018, feedgas flowing into U.S. LNG export facilities during this past winter season reached as high as 5.5 Bcf/day, exceeding pipeline exports to Mexico. The U.S. experienced an early cold start to this past winter season, highlighting significant regional tightness in the domestic gas balance amid a backdrop of historically low storage levels. U.S. LNG exports accounted for a sizeable and steady demand-side risk factor which at times contributed to an end-March storage trajectory of below 1.1 Tcf.

As a result, the day-ahead Henry Hub cash price found itself above $4/MMBtu in a sustained manner near the start of the withdrawal season; please see Figure 3. This would represent the second consecutive withdrawal season in which the Henry Hub cash price signaled significant tightening of the balance since winter 2013-2014 – a trend we expect to continue over the next several years during the winter withdrawal season.

Figure 3
Day-Ahead Henry Hub Cash Price



Sources: NYMEX, Bloomberg, JPMorgan Commodities Research

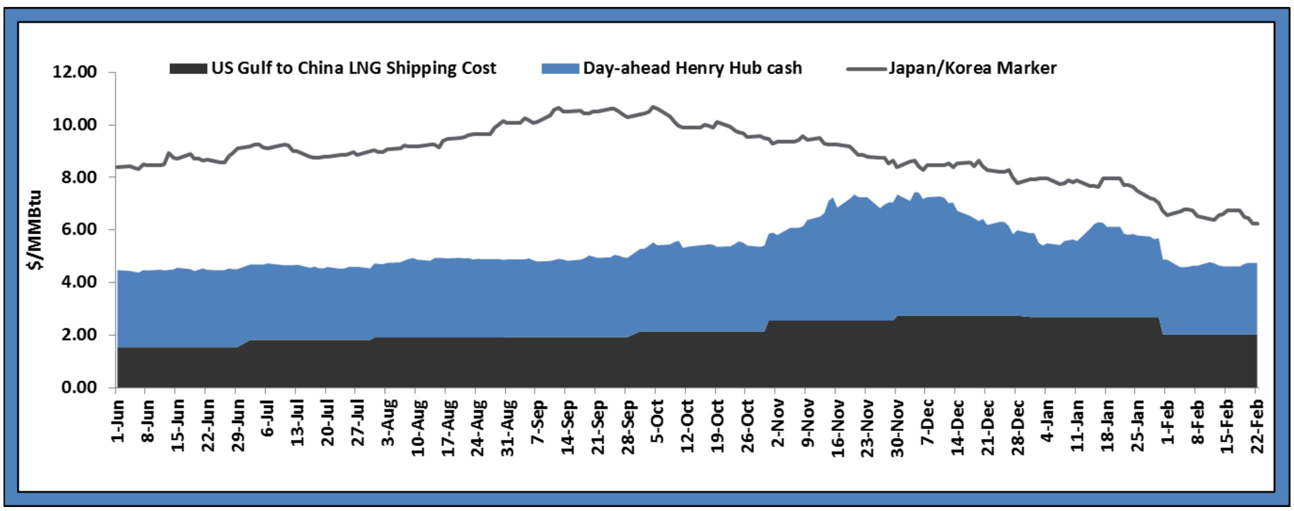
Admittedly, the disappearance of winter-weather did in fact result in the ultimate decline in price during this past winter season. However, when weather-related demand is apparent, growth in organic baseload demand (including from LNG exports) in the U.S. natural gas balance has resulted in increased price volatility, even amid exorbitant production growth.

In fact, the seasonality apparent in LNG demand globally, a winter-driven market much like the U.S. natural gas market, has restored seasonal spreads. An amalgam of weather-related demand side risk factors during winter in the U.S. and abroad supports the natural gas price during the withdrawal season only for that price to fall under pressure in the injection season due to fairly steady production growth and in the absence of weather.

U.S. LNG Hedging Likely to Increase

The price volatility exhibited during this winter season not only caught the attention of gas analysts across the market, but it also drew the attention of natural gas consumers. While a visit above $4.50/MMBtu for a period of time is likely to cause momentary pause for a domestic natural gas consumer, for U.S. LNG consumers abroad that price did diminish netbacks significantly; please see Figure 4. This stands to reason given the rise in LNG shipping costs during the second-half of last year, the precipitous slide in the Japan/Korea Marker as published by Platts, and Henry Hub cash prices rising above $4/MMBtu for a sustained period of time near the start of the withdrawal season.

Figure 4
Diminishing LNG Netbacks



Sources: NYMEX, Bloomberg, JPMorgan Commodities Research

As the natural gas forward curve has shifted into backwardation over the first three calendar years, it has provided an opportunity for consumers to achieve historically low price hedges, especially amid an environment of increased near-term volatility. While calendar strip 2022 and beyond are positioned in an ever so slight contango, 1Q19 price has averaged at a level that is not observed on the NYMEX natural gas forward curve until the December 2027 futures contract. In fact given our assumptions of the current fundamentals for this year, we expect for calendar strip 2019 to average at, or within a few cents of, the current calendar 2026 average price.

Ultimately as summer/winter spreads widen amid growing seasonality, the current shape of the forward curve offers consumers – primarily LNG consumers – a reasonable opportunity to capitalize on a curve structure beneficial for price risk mitigation.

Conclusion

As rising production costs create a soft floor in price – reducing producer hedging activity relative to that seen over the past five years – the morphing of the near- to intermediate tenors of the NYMEX forward curve into backwardation has created opportunities for natural gas consumers to hedge. With U.S. LNG exports growing at a faster pace than any other demand side factor at the current time, it has introduced a new set of consumer participants to the U.S. natural gas market that did not exist before.

Admittedly, it took nearly a decade to destroy the contango that was once so prevalent in the U.S. natural gas forward curve, so the restoration of a contango is one that could take a significant amount of time. That said, the U.S. natural gas market appears to be reaching a stasis in terms of price – weather-adjusted – and we would expect for competitive length procurement to apply some upward pressure in price over the intermediate-term, especially amid upstream cost inflation.

Endnote

For further coverage of the natural gas markets, the reader is invited to read past *GCARD* articles on these markets.

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Revisiting Price Volatility Behavior in the Crude Oil Market

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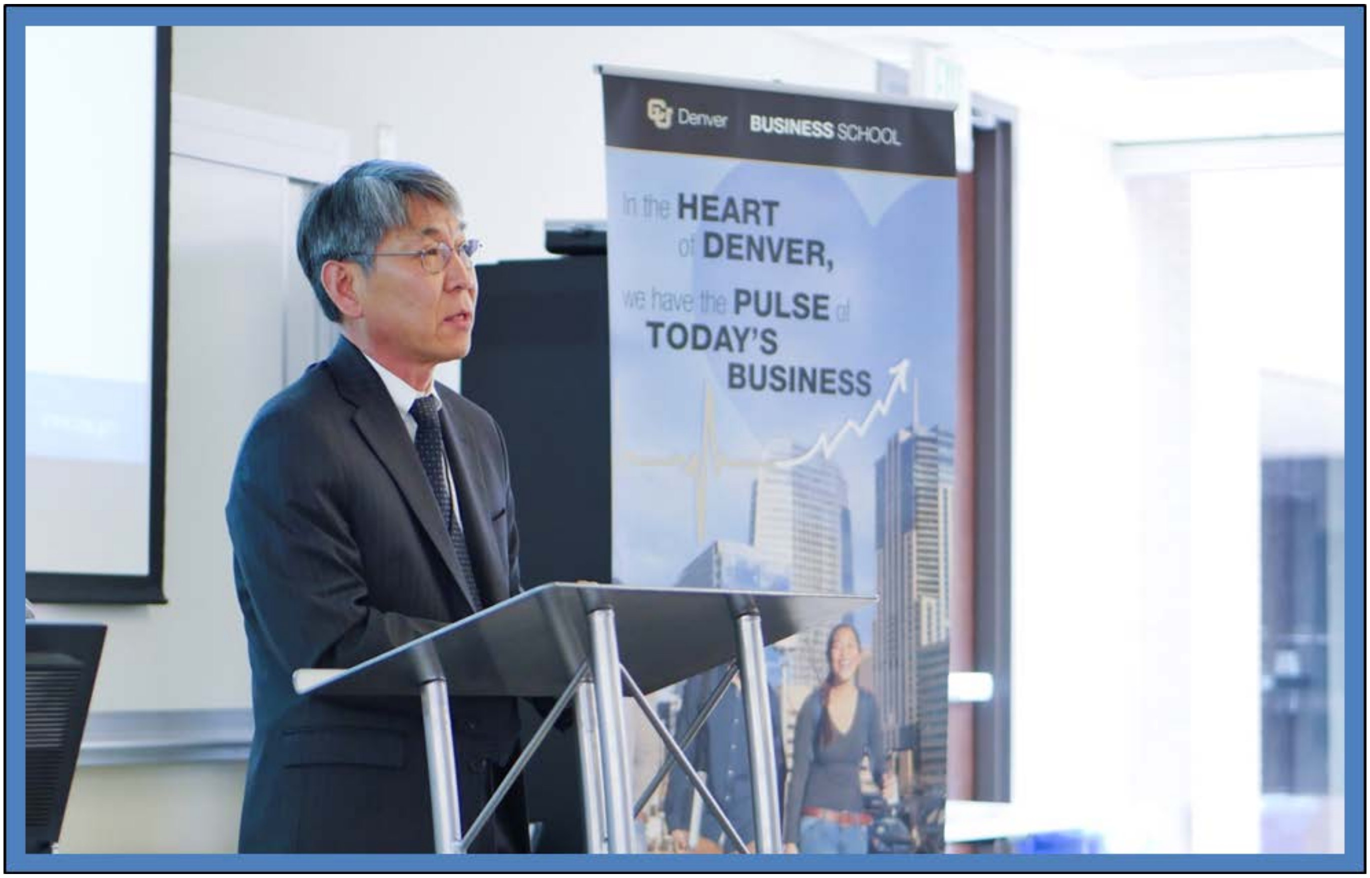


Dr. Thomas K. Lee, Ph.D., of the U.S. Energy Information Administration, presenting at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2018. Dr. Lee, who is also an Editorial Advisory Board member of the *GCARD*, lectured on "Oil Market Dynamics and the Short-Term Outlook."

Introduction

This paper studies the price volatility behavior of the oil markets, updating our previous research on issues related to this topic in Lee and Zyren (2007). But before covering our new study, we will briefly review why oil prices can be so volatile along with the history of highly volatile episodes in the oil markets that have occurred since the mid-1980s.

Generally speaking, changes in price can be large in the oil market since the underlying demand and supply curves are so price-inelastic that shocks to supply or demand will be immediately reflected in the price. Regarding research on this subject, there is no consensus on whether supply shocks or demand shocks are more prone to causing changes in prices. The different magnitude in price response caused by these shocks varies over time, and an increased price caused by unexpected supply restrictions or geopolitical reasons has tended to be transitional.

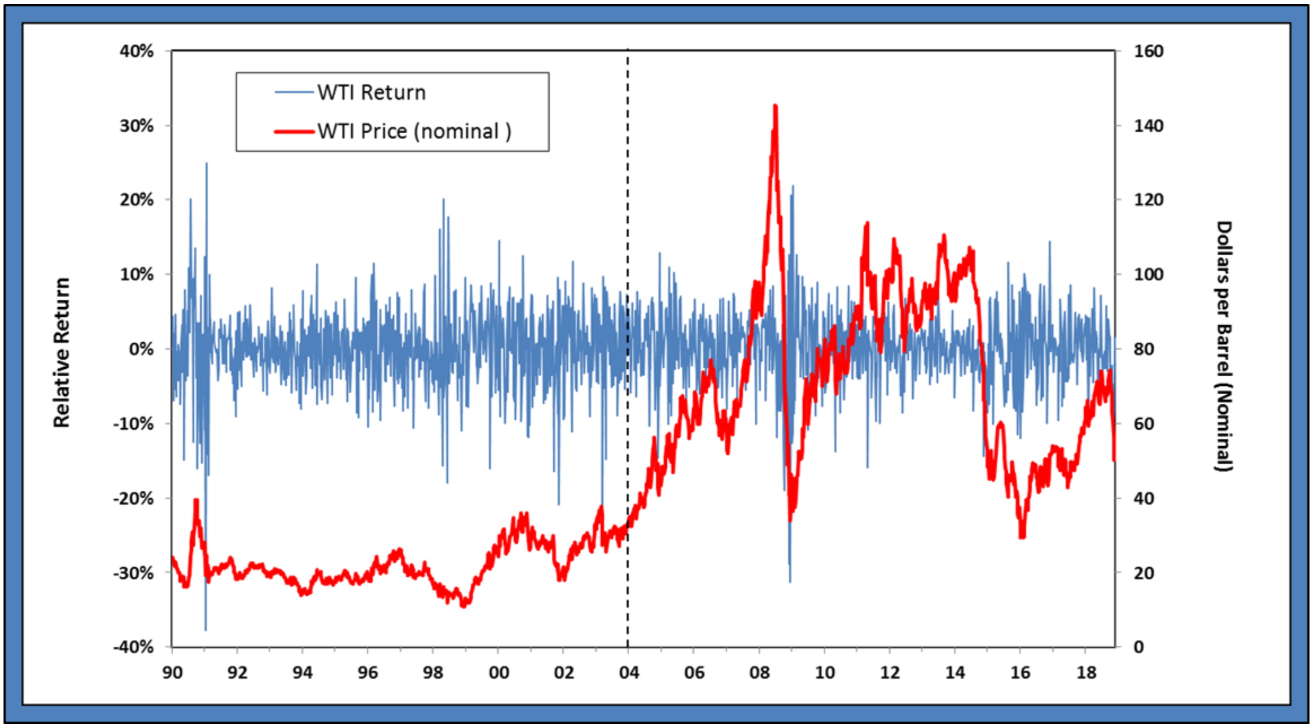
According to a number of academic studies, speculative financial activity in the oil markets, and commodity markets in general, can have some influence on oil prices, but at least historically, there have not been *sustained* price changes caused by such activity. Kilian and Lee (2014) explained and empirically demonstrated, for example, that the 2003-08 oil price surge was mainly influenced by increases in demand, driven largely by the unexpected economic growth of emerging market countries. Prices can also be affected by unexpected fundamental information or announcements. However, such price responses have been very short lived and have not had much long-term impact on volatility.

Figure 1 on the next page shows the percent returns and spot price movement for nominal West Texas Intermediate (WTI) crude oil prices from January 1990 to November 2018. The weekly percent returns show that the volatility of returns varies over time and, as we expect, the price returns exhibit volatility clustering. This implies volatility shocks today could influence the volatility many periods into the future. The nominal prices have historically shown substantial variations, ranging from a low monthly average of $11 in December 1998 to $134 in July 2008. On July 14, 2008, the WTI price registered a level of $145.16, the highest price in history. The price movements in the 1990s were relatively smooth although we had some spikes and downturns with the uncertainty surrounding Gulf War I (1990-1991), the Asian Financial Crisis (1997), and afterwards with the Dot-com Crash (2000-2002). In comparison, oil price movements have widely varied by a larger degree since 2004. There are two noticeable price swings in the oil market after 2004. One occurred during the Global Financial Crisis in 2008 when the oil price peaked at $145 in July 2008 before plummeting to $30 by the end of December 2008, and the other event is the oil price collapse, which took place from the second part of 2014 to early 2016. In the latter episode, the price went as high as $108 in June 2014, followed by a decline to $26 in February 2016.

We can compare the price declines during these two events with the decline in oil prices that occurred in 1985-1986 when members of the Organization of the Petroleum Exporting Countries (OPEC) reversed earlier production cuts. There are different reasons for the various price collapses. The 1985-1986 price collapse was mainly supply-driven whereas the drop in 2008 was mostly due to demand-side factors.

In contrast, the 2014-2016 price collapse appeared to be due to a mix of these two factors. On the supply side, a failure to come to agreement amongst OPEC and non-OPEC producers to control oil production occurred in November 2014, and which was described in Jesse (2017). On the demand side, slowing growth in emerging markets, noticeably in China, also took its toll later on oil prices.

Figure 1
Weekly WTI Price and Return



These types of rapid fluctuations have become of great concern to individual consumers, firms, policymakers and society in general. For each stakeholder, there are different concerns regarding price volatility. For example, from an oil producer's point of view, volatility, whether persistent or transitory, could discourage fixed capital investment due to uncertainty regarding the price path. From a trader's point of view, accurate predictions of price volatility are crucial for arbitrage opportunities since this variable is a key determinant for derivatives valuation. With respect to these concerns, Lee and Zyren (2007) analyzed the volatility interactions between crude oil and petroleum products as well as the magnitude of price volatility in these related markets. The specific interest of this study was to analyze price reactions in both crude oil and the petroleum product markets when OPEC's crude oil pricing behavior changed. This study also hypothesized that the gasoline and heating oil markets would have higher price volatility since these markets have their own set of market factors that would lead to this effect. The study concluded that 1) volatility is higher when OPEC intervenes in the oil market; 2) the price volatility of petroleum products is higher than crude oil; and 3) price volatility for near-month futures contracts is higher than more distant futures contracts.

In our current paper, we are revisiting the fundamental question as to whether the oil price volatility structure is stable over time. This analysis will give us a chance to reevaluate how the composition of the underlying supply, demand, and other exogenous shocks impacts the oil price differently. Both shocks to price and price volatility could be much different today than in earlier periods. Because the effects of shocks change over time and, given technological progress and changing market dynamics, there may be different price impacts resulting from supply or demand shocks as compared to the past.

Understanding the structure of volatility should help us with uncertainty management. One may want to know whether volatility is persistent or transitory and to know its magnitude. If volatility is high and persistent, it may lead firms to rely more heavily on hedging operations and other types of risk management and to place more emphasis on the evaluation of investments in the context of uncertainty. Thus, it is imperative to understand the behavior of crude oil price volatility, its magnitude and duration, as well as its economic implications.

This study on crude oil price volatility is organized as follows. The following section describes the data and empirical methodologies used to estimate volatilities conditioned on types of past information, i.e., "conditional volatilities." The next section summarizes the estimation results and analyzes conditional volatilities in different periods, including a discussion of the analysis' implications. Concluding remarks are in the final section.

Data and Methodology

In order to have a comprehensive understanding of WTI crude oil volatility behavior, we obtained the end-of-week closing prices for the spot and futures markets, including 1-month, 3-month, and 6-month futures contracts, for WTI crude oil.[1] The spot price series were obtained from Reuters while the New York Mercantile Exchange (NYMEX) prices were obtained from Bloomberg. The sample period studied is from January 1990 to November 2018.[2] Table 1 on the next page displays descriptive statistics for both weekly nominal WTI prices and returns for the full period (January 1990 to November 2018), Period 1 (January 1990 to December 2003), and Period 2 (January 2004 through November 2018).

Table 1
Descriptive Statistics for Weekly Nominal WTI Prices and Returns January 1990 through November 2018

Panel a: Nominal Price

	n	WTI Spot	Futures Contract by Month CL1	CL3	CL6
Full Period	*1509*				
Mean		$47.48	$47.49	$47.73	$47.73
Median		37.14	37.14	36.75	37.30
Std. Dev		29.79	29.80	30.06	30.25
Max		145.29	145.29	146.12	146.68
Min		10.83	10.79	11.57	12.33
Period 1	*730*				
Mean		$22.20	$22.17	$21.80	$21.28
Median		20.83	20.86	20.57	20.37
Std. Dev		5.61	5.55	4.99	4.28
Max		39.60	39.69	36.75	33.00
Min		10.83	10.79	11.57	12.33
Period 2	*779*				
Mean		$71.17	$71.22	$72.04	$72.52
Median		68.10	68.35	68.69	69.36
Std. Dev		23.00	22.97	22.48	22.02
Max		145.29	145.29	146.12	146.68
Min		29.42	29.42	31.21	29.90

Panel b: Return (percent)

Return	*n*	WTI Spot	Futures Contract by Month CL1	CL3	CL6
Full Period	*1508*				
Mean		0.0525	0.0525	0.0577	0.0622
Median		0.2548	0.3137	0.3011	0.2589
Std. Dev		5.21	4.99	4.25	3.67
Max		24.99	24.12	21.13	18.60
Min		-37.73	-34.90	-29.56	-21.76
Period 1	*729*				
Mean		0.0480	0.0485	0.0544	0.0559
Median		0.2345	0.2164	0.2541	0.1809
Std. Dev		5.47	5.08	4.10	3.26
Max		24.99	20.05	14.13	12.78
Min		-37.73	-34.90	-29.56	-21.76
Period 2	*779*				
Mean		0.0566	0.0563	0.0609	0.0681
Median		0.2616	0.3809	0.3550	0.3050
Std. Dev		4.96	4.91	4.38	4.02
Max		21.95	24.12	21.13	18.60
Min		-31.22	-31.22	-24.33	-21.05

Table 1 shows that the variation of the nominal price for Period 2 is much higher than for Period 1. The price variation measured by standard deviation in Period 2, which includes the Global Financial Crisis and its aftermath, is four times higher than that of Period 1, with a standard deviation of $5.61 and $23.00 in Period 1 and Period 2, respectively. The price range in each corresponding period, Period 1 and Period 2, is \$28.77 and \$115.87, respectively. Several noteworthy episodes during Period 2 contributed to such a large variation in price (as touched upon in the Introduction), namely: 1) the demand shock resulting from the Global Financial Crisis in 2008; 2) the supply shock arising from OPEC's decision not to steady the oil markets in late 2014; and 3) the demand shocks due to slowing growth in emerging economies in late 2015. In the 2008 episode, within a 6-month period, from the beginning of July to the end of December, WTI spot price declined 77% before rebounding. The declining price journey in the second episode stretched for a year and a half with the price decreasing by 72% from July 2014 to February 2016. These events manifestly led to a large variation in price as compared with Period 1.

We will now turn to formalizing our study of crude oil price volatility with the use of sophisticated statistical models. Since the seminal works of Engle (1982) and Bollerslev (1986), autoregressive conditional heteroskedasticity (ARCH) and generalized autoregressive conditional heteroskedasticity (GARCH) models have found extraordinarily wide use. GARCH models have been very successful at modeling time-varying volatility in financial time series, and they seem to be as good as that of more complex models.[3] In the petroleum markets, Lee *et al.* (1995), Sadorsky (1999), Pindyck (2004), Lee and Zyren (2007), and Salisu and Fasanya (2013) used GARCH models to estimate oil price volatility. The GARCH (p, q) model used in this study is formulated as follows:

$$R_t = \mu + \varepsilon_t \tag{1}$$

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \tag{2}$$

The mean equation, Equation (1), expresses oil price returns as a random walk process with ε_t as the error term. The variance equation, Equation (2), uses the error term, ε_t, of the mean equation to help explain total model variance. In the variance equation, the conditional variance at time *t*, σ_t^2, is specified as a function of three terms: the mean, ω; ARCH terms representing the effect of news in the previous period(s) on current volatility, ε_{t-1}^2; and GARCH terms representing the effect that previous periods' forecast variance(s) have on current volatility, σ_{t-1}^2. The GARCH (1, 1) model is utilized to estimate the conditional volatility for our data series in all three periods.[4] The methodology is based on the assumption that the conditional volatility of the return in oil prices is affected symmetrically by both positive and negative innovations. This means we treat any impact equally, whether it is positive or negative to the price.[5]

Similar to financial data series, energy market volatilities in a period of relative tranquility are often followed by periods of higher volatility. For that reason, an assumption of constant variance over time for the return of oil prices is not appropriate. Thus, to help understand certain aspects of oil price volatility, we utilized the GARCH model for estimating the conditional variance of returns, which allows the conditional variance to be time-variant. However, one must note the usual reservations regarding this model. Our univariate approach does not take into consideration the comovements of returns. To have a better understanding of relevant comovements, one can use the multivariate GARCH (MGARCH) models, which enable the estimation of the relative magnitude of volatilities, systematic information (GARCH effect) and unsystematic information (ARCH effect) in any given time period. While the volatility interaction in MGARCH is an important issue, it is out of scope for this study and we will focus on conditional volatility comparisons only.

Estimation, Results and Implications

Our estimated results can illuminate characteristics of oil price volatility in the spot and futures markets and in different market conditions (Period 1 vs. Period 2). If the sum of ARCH (α) and GARCH (β) coefficients is less than one ($\alpha + \beta < 1$) then the time series exhibit a mean-reversion process. When the sum of these coefficients is equal to one ($\alpha + \beta = 1$) then it is said that the time series follows a random walk. The estimation results in Table 2 on the next page reveal that the sum of ARCH and GARCH coefficients is less than one ($\alpha + \beta < 1$) for both spot and futures contracts in both periods, confirming that oil price volatilities revert back to their historical value after a certain time period. This mean reversion in volatility also means that there is a normal level of volatility to which volatility will eventually return.

Given that oil price volatilities are mean-reverting, we examine their half-lives over our sample periods. The half-life of volatility measures the average time period for the volatility to return back to its mean value in a long-run horizon. It is a measure of volatility persistence. A volatility study of energy markets by Pindyck (2004) concluded that changes in volatility are short-lived with a half-life of 5 to 10 weeks and that volatility has a small positive time trend, which implies little impact on firms' investment activities or on the economy. The half-life volatility in a GARCH specification is calculated by:

$$\text{Half life}_{GARCH} = \frac{\log(0.5)}{\log\left(\sum_{i=1}^{p}\alpha_i + \sum_{j=1}^{q}\beta_j\right)} \tag{3}$$

Our calculations for this specification are also shown in Table 2 on the next page. The conditional variance estimated using a GARCH specification was found to exhibit larger GARCH (moving average) effects than ARCH (autoregressive) effects in all markets and periods. This means that previous period information about observed volatility (ARCH effect) has had much less of an impact on conditional volatility than the previous period's forecast of volatility (GARCH effect). Conceptually, the former measure maps into the effect of news or events during the previous period on conditional volatility while the latter measure maps into the effect of systematic information on conditional volatility.

The speed of mean reversion as calculated by the half-life method reveals that the half-life for Period 1 is about 12 weeks while for Period 2, the half-life is about 18 weeks, as shown in Table 2 below. This indicates that there is more of a persistent volatility condition in the second period as compared to the first period. We believe this persistence is mainly due to two events: the 2008 Global Financial Crisis and the 2014-2016 oil price collapse.

Table 2
Crude Oil – Volatility Estimation Results

Panel a: Period 1 (January 1990 through December 2003)

	Spot	Futures Contracts		
	Cushing	1	3	6
n	729	729	729	729
Constant	0.000194	0.000160	0.000074	0.000039
	(3.01)	(3.02)	(3.06)	(3.51)
ARCH(1)	0.160482	0.129159	0.104048	0.085116
	(5.09)	(4.64)	(5.26)	(5.48)
GARCH(1)	0.781624	0.815481	0.856804	0.881403
	(17.09)	(19.47)	(29.11)	(40.87)
Sum	0.942	0.945	0.961	0.967
Half-life	11.6	12.2	17.4	20.4

Panel b: Period 2 (January 2004 through November 2018)

	Spot	Futures Contracts		
	Cushing	1	3	6
n	779	779	779	779
Constant	0.000088	0.000085	0.000067	0.000055
	(2.64)	(2.74)	(2.79)	(2.92)
ARCH(1)	0.090090	0.090815	0.080472	0.085293
	(4.98)	(5.15)	(4.43)	(4.50)
GARCH(1)	0.871739	0.871106	0.884084	0.881516
	(31.11)	(31.91)	(32.98)	(33.99)
Sum	0.962	0.962	0.965	0.967
Half-life	17.8	17.9	19.2	20.5

Note: Z-statistics are in parentheses.

We will now examine implied volatility in the crude oil futures market. Implied volatility provides a measure of market participants' expectations of uncertainty regarding future price movements. This measure is also known as a proxy for investor sentiment. Although crude oil and stock markets often move independently because of different factors affecting each market, the price volatility of these markets can often be positively correlated. There are four noticeable market uncertainty spikes in oil implied volatility (OVX), which took place in 2008, 2011, 2014-16, and in 2018. Reviewing Figure 2 below, we see that the stock market implied volatility (VIX) spiked with similar magnitudes as the OVX during the Global Financial Crisis in 2008 and the Libyan crisis of 2011. But the OVX's pattern during the oil price collapse in 2014-2016 is very different from what the equity markets experienced: the OVX's spikes are much higher than those of the VIX. The higher implied volatility in the oil market as compared with equity volatility was also witnessed in November 2018 when the market became concerned with the slowing growth in demand and oversupply issues.

Figure 2
Weekly VIX and OVX Indices (in Percent)

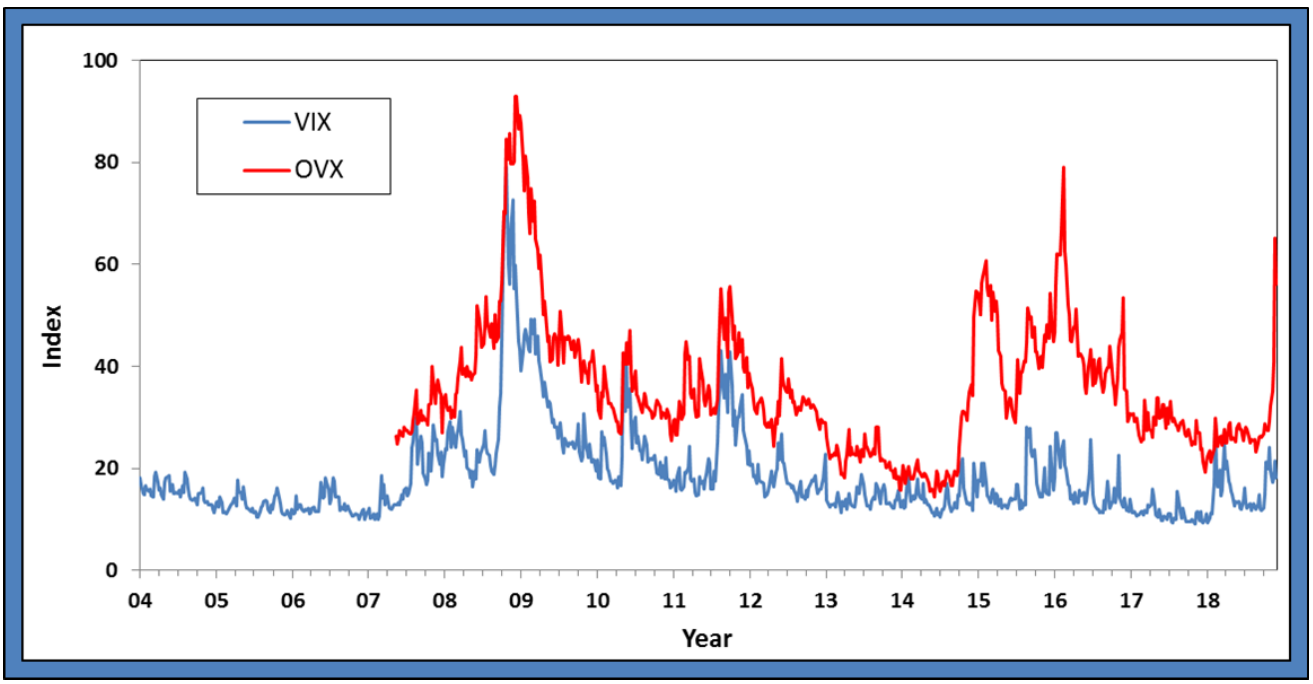


Figure 3
Weekly WTI Historical and Conditional Volatility Comparison

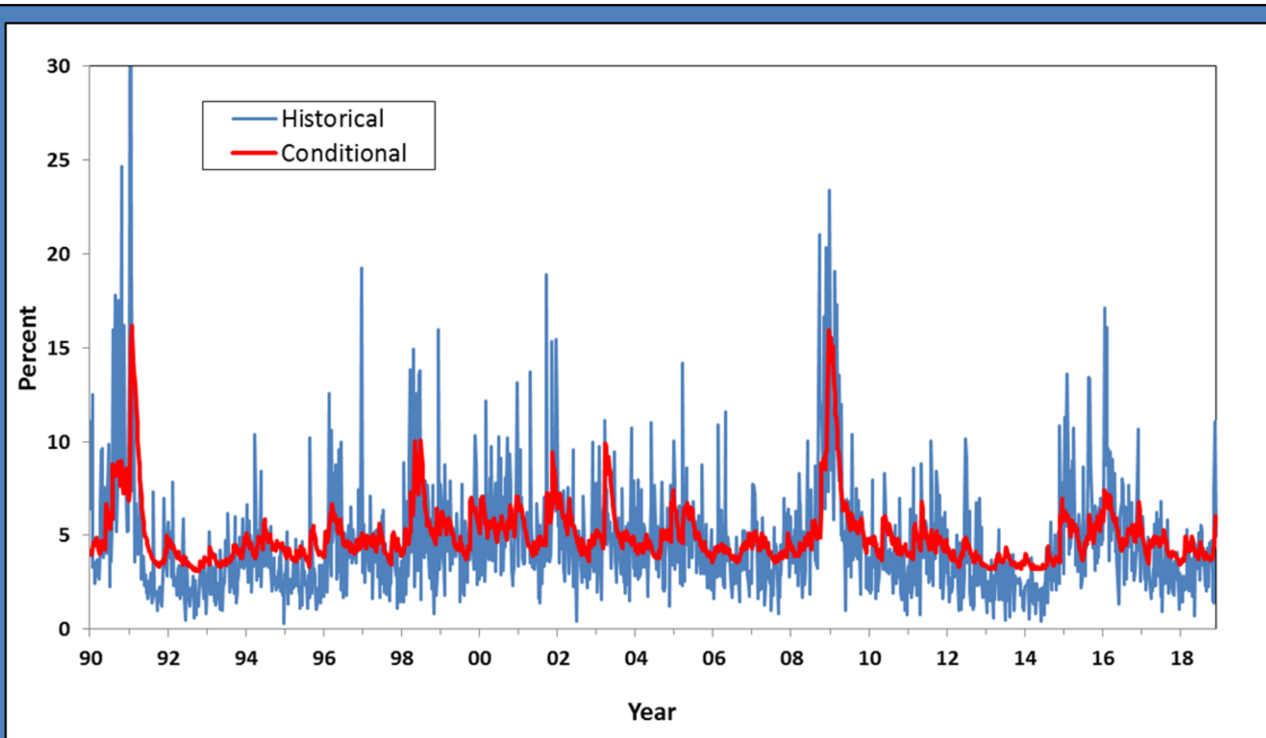


Figure 3 above provides a comparison between the historical and conditional volatilities of weekly crude oil returns for the entire sample from January 1990 to November 2018. The estimated conditional volatility captures major events in the sample period; thus, it appears that the model is reasonable and acceptable. However, the conditional volatility fails to capture a number of the weekly spikes, especially for the 2014-2016 period. During this period, the pattern and size of the OVX is about the same as the historical volatility, but the estimated conditional volatility did not exhibit the magnitude of this uncertainty. The ARCH effect in the conditional volatility is also diminishing in the second period relative to the first one. This may be due to the fact that with the advent of 24-hour electronic trading and technology improvements (e.g., algorithmic trading), the volatility reaction to surprise shocks has become quick and diminishing (Ederington *et al.* (2019)). We may need to refine the specification or use other models to deal with this issue.

Conclusion

The goal of this paper has been to provide an updated analysis of crude oil volatility, incorporating more recent data than our original work in Lee and Zyren (2007). In our current paper, we compared the behavior of oil price volatility during two different time horizons: 1990 to 2003 and 2004 to 2018. We empirically examined the conditional volatilities and volatility persistence in the oil markets during very eventful times. Our results suggest two important findings: 1) the component of oil price volatility due to current information has diminished more quickly than previously while 2) the systematic information component of oil price volatility has persisted longer than previously.

Another way of framing our results is that while the price reactions due to current news or events have not been as important as in the 1990s or early 2000s, we also documented an increasing pattern of volatility persistence in the more recent data. The persistence of price volatility in the oil market may negatively impact business investment decisions and/or economic activity as a whole. To build confidence in our results, though, we recommend that researchers use different specifications and models than our GARCH specification in studying these issues.

Although this study documents that the recent level of volatility is higher than that of earlier in the decade,[6] we have not addressed what has caused this phenomenon. It is an important issue to have a better understanding of the drivers of volatility behavior in the oil market. There may be several or many different reasons for the change in price volatility conditions. The candidate hypotheses include fundamental changes in market conditions such as the shale revolution, technology advancement, and geopolitics, but a definitive answer awaits future research.

Endnotes

1 Lee and Zyren (2007) used daily data for WTI, conventional and reformulated (RFG) gasoline, and heating oil in both New York Harbor (NYH) and U.S. Gulf Coast (USG).

2 The data period in Lee and Zyren (2007) was from January 1990 to May 2005.

3 Hansen and Lunde (2005) argue that the best volatility models do not provide a significantly better forecast than the GARCH model. See Poon and Granger (2003) for a comprehensive review of alternative methods for estimating and forecasting volatility.

4 The Lee and Zyren (2007) study included a shift variable, capturing a structural break. Specifically, the shift variable indicated how OPEC's decision to create a new price regime in April 1999 impacted the mean of the conditional volatility. However, our main aim in the current study is to see whether volatility behavior has changed in the 2000s with the Global Financial Crisis and the oil supply glut period.

5 This assumption is not appropriate when petroleum products prices are evaluated. Lee and Zyren (2007) applied the threshold-GARCH (TARCH) process to estimate the conditional variance for gasoline and heating oil prices, given asymmetric responses of petroleum product prices. They found that the heating oil market and the one-month futures contract in gasoline seem to exhibit "leverage effects," i.e., an asymmetric tendency for volatility. Ederington *et al.* (2019) provide a survey of the literature on volatility and asymmetric responses of product prices.

6 McNally (2018) also discussed concerns with heightened oil price volatility.

The views expressed in this paper reflect the opinions of the authors only. It is not meant to represent the position of the U.S. Department of Energy or the Energy Information Administration, nor the official position of any staff members. The authors are solely responsible for all errors and omissions.

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Author Biographies

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Dr. Thomas K. Lee has been with the Office of Energy Markets and Financial Analysis at the U.S. Energy Information Administration (EIA) since 2010. As a senior economist, he is mainly responsible for the research and analysis of issues related to financial market and physical oil market linkages, focusing on factors that influence oil prices and volatilities and the relationship between financial market activities and oil prices. Most of his recent research has focused on the sources of fluctuations in the price of oil and petroleum products. He is also responsible for variables and modeling issues beyond the physical fundamentals of oil prices in the National Energy Modeling Systems (NEMS) to support the EIA's core publications, *Short-Term and Annual Energy Outlook* (*STEO*). Prior to this role, he served as Industry Economist for the Office of Integrated Analysis and Forecast at EIA from 2001 to 2010.

Dr. Lee also had been associated with Marymount University as a finance faculty member from 1999 to 2010. He has published scholarly articles in a number of journals including *Journal of International Money and Finance, Journal of Applied Econometrics*, *Journal of Energy Markets*, *Energy Economics*, *Energy Journal*, *International Advances in Economic Research*, *Atlantic Economic Journal*, *Journal of Derivative Markets*, and *International Finance Review*, among others. He received an M.A. in Finance and a Ph.D. in Economics from the Catholic University of America.

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Dr. John Zyren has been employed at the EIA from 1993 and with the Office of Energy Markets and Financial Analysis since 2013. As a senior industry economist/econometrician he has been responsible for the analysis and forecasting of crude oil and petroleum product markets. His current research interests include improving the analysis/forecasting methodology for EIA's *Drilling Productivity Report* (a monthly publication which uses estimates of drilling productivity and estimated changes in production from existing oil and natural gas wells to provide estimated changes in oil and natural gas production for seven key regions.)

He has published scholarly articles in a number of journals including *Atlantic Economic Journal*, *Journal of Energy Markets*, *International Advances in Economic Research*, *Energy Policy*, and *International Journal of Forecasting*, among others. He received his degree in Economics from the North Carolina State University. In his early professional career, he worked at the U.S. Department of Agriculture and the National Food Processors Association.

An Analysis of Agricultural Block Trading

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Significance of Block Trades

The Chicago Mercantile Exchange ("CME") launched block trading for the full suite of agricultural futures and options on futures products on January 8, 2018. Prior to this action, the CME had allowed block trades for only eleven (mostly smaller) products in the agricultural asset class.

Block trading is an important issue for the CFTC because of Designated Contract Market (DCM) Core Principle 9 of the Commodity Exchange Act which states that "[t]he board of trade shall provide a competitive, open, and efficient market and mechanism for executing transactions that protects the price discovery process of trading in the centralized market of the board of trade."[1]

Prior to the CME's expansion of agricultural block trading in January 2018, the CFTC heard various concerns from some members of the industry – most importantly, that block trades could reduce liquidity from the central limit order book ("CLOB") and could reduce price transparency.

Since the January 2018 implementation of agricultural block trading in larger markets, the CFTC's Division of Market Oversight ("DMO") staff has heard continuing concerns that block trades are occurring in liquid front months and prices of some block trades appear to be outside the range of current prices.

DMO staff has taken these concerns seriously and made recommendations to the CME. DMO staff has also undertaken a data-driven analysis of all futures block trades from January 2018 through September

2018 in order to keep the Commission and industry participants informed on this issue. This report updates DMO staff's initial analysis of data from January 2018 to March 2018 ("initial analysis").[2]

Key Questions and Answers

DMO staff designed its analysis to answer several questions related to industry concerns. A summary of the questions and answers follows.

How large is agricultural block trade volume relative to total agricultural volume?

Similar to the initial analysis, block trades are insignificant compared to total volume, but block trades can be a significant percent of the total volume in an individual contract month on specific days.

Are agricultural block trades displacing total agricultural volume?

Similar to the initial analysis, DMO staff observed no increase in block trade volume relative to total volume.

Are agricultural block trades occurring in nearby months?

Over 63% of block volume is in the nearby months versus 75% in the initial analysis.

Are agricultural block trades pulling liquidity away from the CLOB?

Almost 57% of block futures volume is being offset in the CLOB for the same contract expiration on the same day versus 65% in the initial analysis.

Are block trades being executed at "fair and reasonable" levels in accordance with CME rules?

Similar to the initial analysis, they are in compliance with CME rules.

Methodology Overview

DMO staff analyzed all grain, oilseed, and livestock transactions from January 8 through September 30, 2018. This amounted to an analysis of millions of records.

DMO staff sourced the block trade and position data from proprietary data submitted to the CFTC. DMO staff sourced order book, market volume, and price data from Vertex and DTN. Additionally, DMO staff used the CME Advisory Notice (RA1719-5R) and CME Rule 526 to evaluate the "fair and reasonable" price standard for block trades.

DMO staff identified 389 futures blocks (52 outright and 337 spreads) and 485 options on futures blocks (81 outright and 404 spreads). Each apparent spread transaction was counted as two separate legs because that is how they are cleared. The reason for the odd number on the legged spreads results from a corn/ethanol spread block. Since ethanol is not part of this study, DMO staff excluded it from the analysis. One of the reasons traders sometimes execute block trades is for these more exotic spread trades, such as this corn/ethanol spread.

For this study, DMO staff included futures and options in the volume summary statistics, which are displayed in Figures 1 to 4 below. Block option volume is not delta adjusted in this report. DMO staff focused the detailed pricing and liquidity analysis in Figures 5 and 6 below on futures-only block trades due to the complexity of options and the relatively small value of options on a delta adjusted basis.

Figure 1
Block Trades Percentage (Futures and Options)

Commodity	All Days	Days when Blocks Occur
CBT CORN	0.32%	1.29%
CBT WHEAT-HRW	0.17%	2.58%
CBT WHEAT-SRW	0.16%	0.86%
CBT SOYBEANS	0.15%	1.22%
CBT ROUGH RICE	0.14%	6.05%
CBT SOYBEAN OIL	0.11%	1.60%
CME LEAN HOGS	0.08%	2.21%
CBT SOYBEAN MEAL	0.08%	0.88%
CME LIVE CATTLE	0.02%	0.36%
Average	**0.19%**	**1.22%**

Similar to the initial analysis, blocks are an extremely small percentage of total futures and options volume (0.19% above versus 0.17% in the initial analysis).

The middle column of Figure 1 compares block volume to total volume. Every agricultural commodity's share of block trades is well below one percent with an average of about 1/5 of one percent. This demonstrates that block trading is not a significant share of the market and that blocks could not consistently impact price discovery.

The right column of Figure 1 displays block volume on days when blocks actually occur. On approximately 18% of the trade days, no block trades are executed in any of the agricultural markets analyzed, so the prevalence of many "zero" observations skews the data downward in the "All Days" column. When removing the dates with no block trades from each commodity and then comparing block volume with total volume, block trades are still very small, averaging about 1.2% of total volume.

Figure 2
High Block Volume Days (Futures and Options)

Date	Contract Month	Contract Market	Block Volume	Block Share of Volume
3/27/2018	Mar-19	CORN	3,006	47.7%
4/13/2018	Mar-19	WHEAT-SRW	1000	45.0%
4/16/2018	Jul-19	WHEAT-SRW	500	44.4%
2/2/2018	May-18	LEAN HOGS	187	42.4%
4/26/2018	Jul-19	WHEAT-SRW	381	40.4%
4/27/2018	Jul-19	WHEAT-SRW	381	35.1%
5/15/2018	Dec-19	WHEAT-SRW	242	34.6%
7/12/2018	Nov-19	SOYBEANS	1600	34.5%
3/29/2018	Jul-18	WHEAT-SRW	200	31.7%
2/1/2018	May-18	LEAN HOGS	200	30.3%

Figure 2 shows the top block percentages of volume by date and individual contract month. Industry participants' concerns may have been driven by these larger percentages, which may be misleading because the volume in Figure 2 represents deferred and therefore generally thinly traded contract months. For example, in row one, on March 27, 2018, a deferred month March 2019 corn block trade totaled 3,006 contracts. This represented over 47% of the volume for that one contract month on that specific day. A more nearby month example is found in row four where on February 2, 2018 a Lean Hog block trade in the May 2018 contract totaled 187 contracts. It is important to note that May Lean Hogs is traditionally a seasonally thinly traded futures contract month, so a modestly-sized block trade can easily make up a large share of volume.

Such large block percentages of the total volume may cause concern amongst the industry. However, the block trades in a thinly traded Lean Hog May contract or blocks executed in deferred contracts appear to be within the expectations that the CME had when they chose to implement block trades. It appears these trades support the CME's intent of block trades – to fulfill trading in less liquid months.

Figure 3
All Futures and Options Combined (AFOC)
(Futures and Options - Block Option Volume is Not Delta Adjusted)

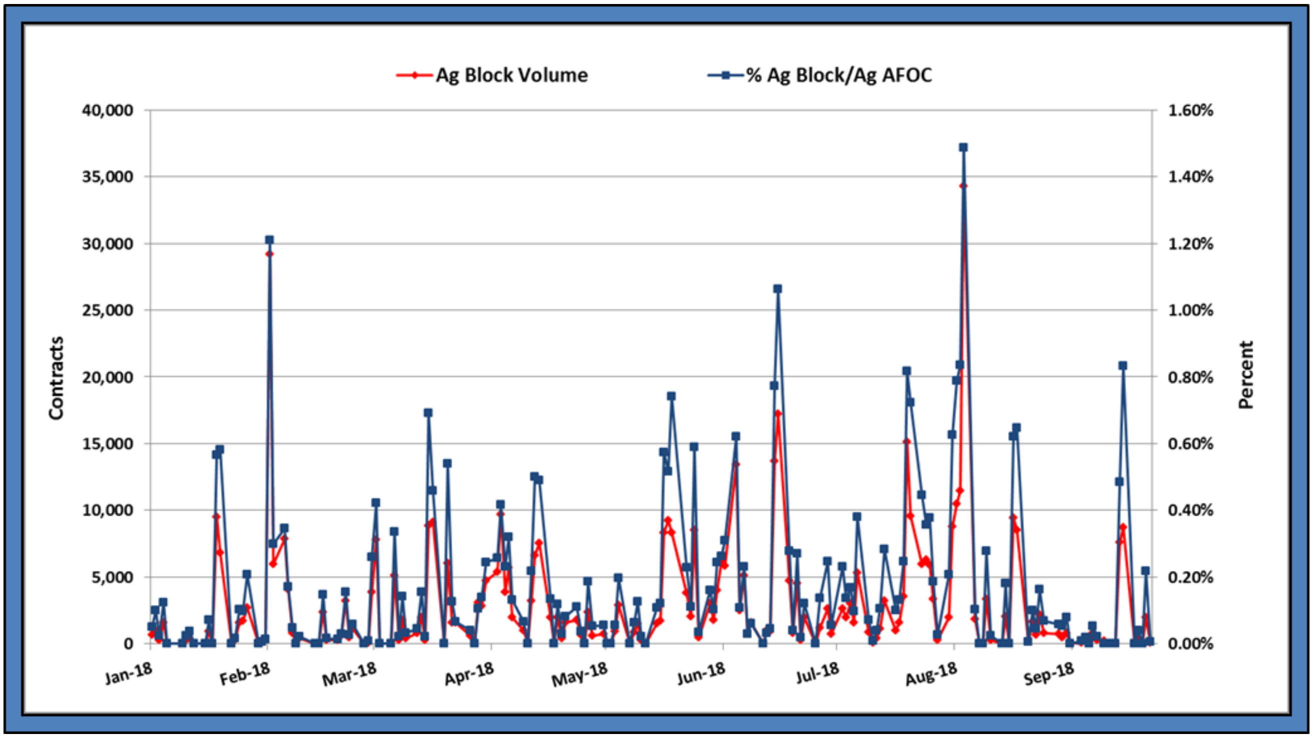


Figure 3 shows agricultural block volume (red line using the left axis) versus agricultural block volume as a percent of total agricultural volume (blue line using the right axis).

In Parkin and Bunge (2018), the National Grain and Feed Association expressed a wariness "of increasing futures volume moving into blocks … [fearing] if volumes grow too large it could limit market participation, especially for relatively smaller hedgers." The data shows that the number of block trades is not increasing and, as Figure 3 demonstrates, the block volume and block share of volume are also not increasing.

Of note, the large block volume of almost 30,000 contracts on February 8, 2018 was primarily due to two large block corn spread trades. That block trade volume was the second highest percentage observed to date at 1.2% of total agricultural volume. On that day, blocks accounted for about 4% of the March corn volume and 6% of the May corn volume. The largest block volume of 34,278 contracts occurred on August 10, 2018. It primarily consisted of vertical call spreads in corn and soybeans, with deep out-of-the-money call options. Adding the delta adjusted options to the futures results in a futures equivalent volume of about 7,000 futures contracts. When viewed from a futures equivalent volume, this block volume is less significant.

Figure 4
Nearby (< 90 days) versus Deferred Blocks (Futures and Options)

"Nearby" if futures expiration within 90 days. All futures and options data		
	Percent Share	
	NEAR	DEFERRED
ROUGH RICE	100%	0%
LIVE CATTLE	87%	13%
SOYBEAN MEAL	71%	30%
WHEAT-HRW	66%	34%
CORN	66%	34%
SOYBEANS	62%	38%
LEAN HOGS	57%	43%
SOYBEAN OIL	51%	49%
WHEAT-SRW	46%	54%
Grand Total	63%	37%

Figure 4 shows that on average 63% of the agricultural block trade volume is occurring in the front two (generally most liquid) months. This is lower than the 75% number found in the initial analysis.

The industry concern is that block trades are pulling volume from liquid contracts. As an example, on February 8th the March-May corn spread volume was about 125,000 contracts for the day. Of that specific spread volume, there were two large block trades that accounted for almost 14,000 contracts. This concerned the industry because the use of block trades in liquid contracts appears to conflict with the expectations set by the CME in the pre-launch of block trades. Prior to the launch of agricultural block trading, the CME publicly opined that blocks would primarily be traded in deferred and thinly traded contracts. There is no rule violation in trading nearby block months, but due to these statements and industry expectations, nearby month block trades are likely getting the industry's attention.

Although declining as a percent of total block volume when compared to the initial analysis, block trades are still occurring mainly in the nearby months. DMO staff notes, however, that some of the nearby block volume occurs due to the large number of spread trades where institutional traders are executing a nearby leg with a deferred leg on a spread. Nearby block volume as a percent of total block volume remains significantly higher than in deferred months, but a large portion of these nearby month legs are being traded as blocks because of the thinly traded deferred month leg. Therefore, the high percent of block volume in nearby months is not indicative of outright trading, but rather to the nearby month trades being tied to spread trades with less liquid deferred months. This is seen in the high percent of block spread trades. About 85% of agricultural block trades are spread trades versus 90% in the initial analysis.

Block Trades and the Central Limit Order Book

Block trade sizes can be large relative to the available liquidity in the CLOB. Generally, if a large market order is entered into an illiquid contract that market could experience price and volume spikes that could trigger logic events – temporary trading pauses. The impact of a large order could trigger prices of resting orders to be traded through rapidly, only to snap right back – possibly even causing a flash crash. Because the liquidity in some markets is not large enough to accommodate the execution of larger sized orders, participants may be harmed. Entering an order as a block trade and having a market-maker offset it over time could help to buffer sudden wide price moves in thinly traded markets. Some industry participants, particularly hedgers, who have expressed concerns that block trades take liquidity away from the CLOB, may be discounting the buffering effect that block trade offsetting can have on sudden price swings.

DMO staff analyzed this concern by focusing on identifying and measuring the block trades that are being offset in the CLOB. DMO staff took a conservative approach to measuring which block trades are being offset in the CLOB. For this study, the term "offset" means a trader transacted the opposite side of their block trade in the CLOB on the same day, same contract, and same month as the block trade. DMO staff opted to keep a narrow offset methodology to assure the offsets are not overstated.

Figure 5
Blocks Offset in the CLOB (Futures Only - No Options)

Activity in the CLOB versus Blocks			
Contract	Block Volume	Activity in the CLOB Opposite the Block by Block Participant	Percent
ROUGH RICE	254	214	84%
LIVE CATTLE	1,681	1,275	76%
SOYBEANS	8,182	4,980	61%
LEAN HOGS	7,808	4,689	60%
CORN	112,046	67,230	60%
WHEAT-SRW	30,164	16,310	54%
SOYBEAN MEAL	10,894	5,865	54%
WHEAT-HRW	21,038	9,847	47%
SOYBEAN OIL	11,840	4,758	40%
Grand Total	203,907	115,168	**57%**

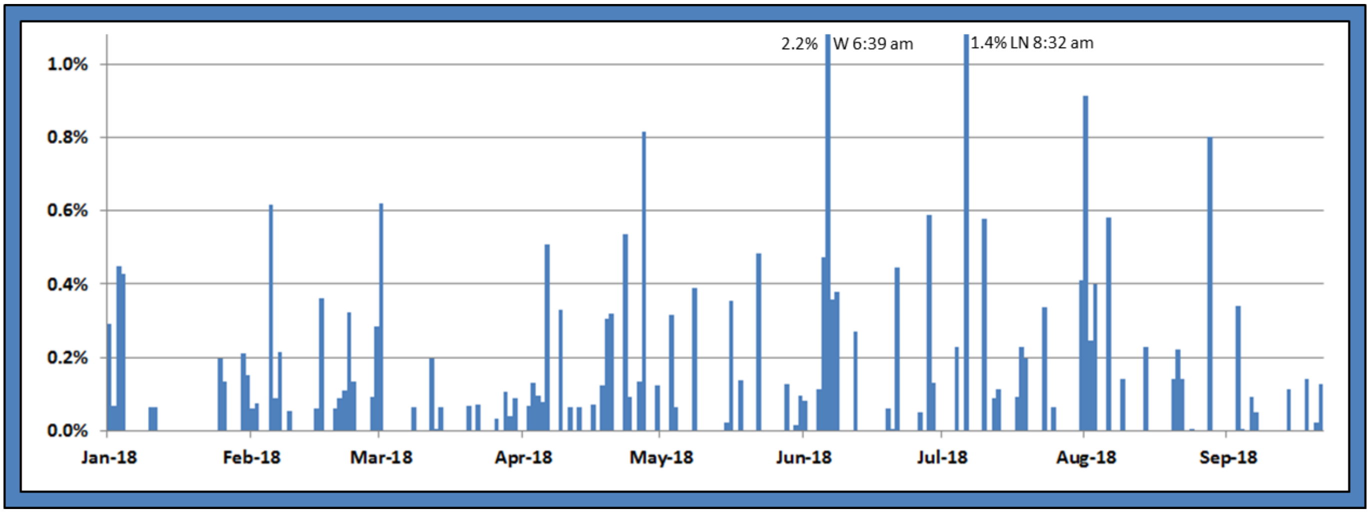
The far right column in Figure 5 shows the percentage of blocks offset into the CLOB by product. DMO staff observed a fairly large range from 40% to 84%. The average percent offset in the CLOB for all agricultural products examined is 57%, which means, if two participants execute a block, 57% of that volume hits the CLOB for that trade date. This is compared to 64% in the initial analysis. The market maker of those block trades executes trades in the CLOB on the opposite side of the blocks. So, if a market maker buys via a block it will sell in the CLOB to offset that trade, and vice-versa. The market maker has an incentive to offset the trade in an orderly manner to minimize price impact so as to minimize slippage and maximize the profit of the arbitrage.

DMO staff also learned, through trader interviews, that some traders use blocks in place of swaps and this could add liquidity when those blocks are offset in the CLOB. In that case, it could be that blocks are adding to total liquidity and volume of the CLOB or, at a minimum, not causing any harm.

Figure 6a
Block Pricing (Futures Only - No Options)

% Off-Market	# of Blocks	% Blocks	Cumulative Block %	Within Days Price Range
0.0%	248	63.8%	63.8%	YES
0.1%	64	16.5%	80.2%	YES
0.2%	19	4.9%	85.1%	YES
0.3%	25	6.4%	91.5%	YES
0.4%	14	3.6%	95.1%	87.5%
0.5%	8	2.1%	97.2%	80.0%
0.6%	4	1.0%	98.2%	YES
0.7%	1	0.3%	98.5%	YES
0.8%	2	0.5%	99.0%	YES
0.9%	2	0.5%	99.5%	YES
>=1.0%	2	0.5%	100.0%	YES
Grand Total	389	100.0%		99.5%

Figure 6b
Off-Market Price Percentage



The table in Figure 6a displays the distribution of the variance of the block price from actual market prices in a 15-minute period just prior to the block trade. The first column on the left hand side displays the percentage that the block price varies from the market price ("off-market" price).[3] For example, row 2 shows that 80.2% of the block trades varied 0.1% or less from the actual open market trade prices. Also, the row just above "Grand Total" shows two block trades were executed at greater or equal to 1% "off-market" price. The far right column displays two rows with shaded cells reading "87.5%" and "80%". These represent two different rice block trades that traded slightly out of the daily range, but were deemed acceptable by CME rules based on order book depth.

The chart in Figure 6b displays the off-market price percentage chronologically over the nine-month period examined. DMO staff observed that 80% of the bar tops are under the 0.1% line. The highest variances of the block prices from the actual market prices were a 2.2% variance in a SRW Wheat block executed at 6:39 AM and a 1.4% variance in a Lean Hog block executed at 8:32 AM. These outliers show two prices off the market but it should be noted both occurred within the daily trading range.

The CME requires trades to be executed at a fair and reasonable price. One of the main components of the "fair and reasonable" rule is that block trades must be executed within the day's trading range. All but two (acceptable rice trades noted above) of the futures block prices that DMO staff analyzed were executed within the trade date's trading range which, during any given day, can be quite wide. DMO staff makes no judgment on the CME rule, but is confident the analysis shows the CME rule is being enforced correctly.

Conclusions and Takeaways

Block trades in the agricultural space are a very small portion of the overall volume, but are somewhat more significant on specific dates and for certain contract months.

Block trades are primarily occurring in nearby months.

Market makers appear to be offsetting more than half of the block volume into the CLOB.

The prices of blocks appear to be priced within the CME rule for "fair and reasonable" prices.

DMO staff will continue to monitor block trades, looking for examples of:

- Block prices outside the normal trade range.
- Liquidity being pulled away from the front months.
- Block trade volume being offset in the CLOB.

DMO staff regularly speaks to the agricultural community through trader calls and will continue to engage the industry as block trades have been a large concern since the expansion in 2018.

Endnotes

1 7 U.S.C. 7(d)(9).

2 See "Agricultural Block Trade Analysis," A Report by Staff of the Market Intelligence Branch, Division of Market Oversight, U.S. Commodity Futures Trading Commission, July 2018, https://www.cftc.gov/MarketReports/StaffReports/index.htm.

3 "Off-market" is defined as variance from the daily trading price band as described on this CME webpage.

Disclaimer: This is a report by staff of the U.S. Commodity Futures Trading Commission. Any views expressed in this report are solely the views of staff, and do not necessarily represent the position or views of any Commissioner or the Commission.

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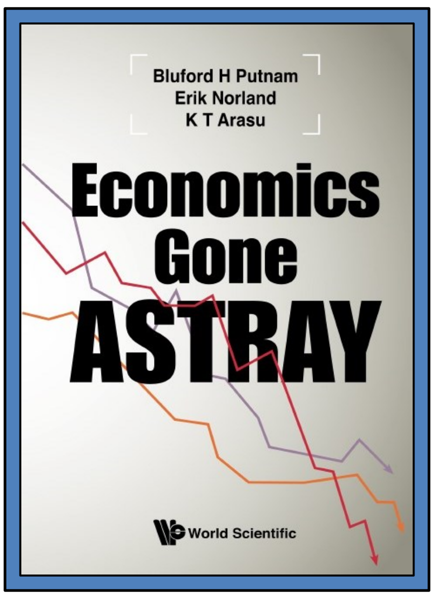
Book Review: Economics Gone Astray

Tina Marie Reine
Commodity Markets Consultant

Rarely can I read a book on the dismal science of economics without getting frustrated or bored or both. Frustration comes from the dependence on mathematics, which I view as a crutch. Boredom comes from the lack of applicability to reality I observe every day in the commodity markets with which I am involved. I am happy to report that Economics Gone Astray, written by Blu Putnam and Erik Norland, and edited by KT Arasu, is a great read and helped me to appreciate why I have become so cynical about modern economics as taught in university and often practiced in policymaking or in financial forecasting.

Economics Gone Astray is destined to become a classic, as a supplemental text for basic economics as well as graduate level courses in macroeconomics. It is written in clear English, without equations, and with plenty of charts to ground one's understanding in the real world. The theme that drives the analysis is that many economists, certainly not all, make the same mistakes over and over again. If you only read the "Introduction," you will gain an appreciation of the authors' perspective on their profession and it will fundamentally change how you view economic analysis. And, the "Introduction" prepares one for a set of informative case studies on such timely topics as the lack of inflation pressure, the growth implications of tax cuts, the demographic challenges to growth, why machine learning will have some hard challenges as a tool for portfolio management, why quantitative easing did not create growth or inflation, and much more.



So, let's cut to the heart of why economics has gone astray. Blu Putnam and Erik Norland argue that economists often make three mistakes.

First, economists rely heavily on simplified mathematics that embed highly unrealistic assumptions about which they completely forget when they apply the models to policymaking or to financial forecasting. The problem is not the use of mathematics, which can go a long way to tighten one's logic. The problem is ignoring the simplifying assumptions when making real world applications. Take the famous Black-Scholes options pricing model. It assumes we live in a world of no taxes and unlimited borrowing. But those two heroic assumptions do not cause most of the problems when applying the model. The challenges and real-world mistakes often can be traced back to the assumption that there are no price gaps or breaks in markets – that is, when a surprise hits a market and the price instantly moves with a big gap either higher or lower. If risk managers look at implied volatility based on Black-Scholes they may misestimate future volatility and ignore the big risks associated with price breaks. This happens with event risk, such as Brexit. Before the event, the market prices two divergent scenarios, and then once the outcome is known the market moves instantly to reflect the new reality. Price gaps can destroy an options delta-hedging strategy and hugely impact vega (volatility shifts) risk management approaches. One needs to remember that most implied volatility calculations totally ignore price gaps and give very misleading signals.

Second, economists often live in a linear world and arguably are guilty of flat-earth thinking. Virtually nothing in markets or economies moves in a straight line. One of the favorite statistical tools of economists is linear regression, which embeds the assumption that the estimated parameters are fixed for the duration of the period under observation. Unfortunately, in this dynamic world of ours, this assumption that critical parameters in one's economic model are fixed over time can lead to disaster. Take the estimation of oil production based on the number of rigs. Shale oil wells using hydraulic fracturing are way more productive than older traditional wells. And, while some folks like to think of the fracking revolution as a one-time shift of technology, nothing could be further from reality. Shale oil and natural gas burst on the U.S. scene over ten years ago, and each year the technology has become more efficient and cost effective. It is not just that shale wells produce more oil than traditional wells, they produce more oil for less cost than a shale well of only a few years vintage. Linear extrapolation is embedded in the economists' toolkit and biases the profession way too much toward simple answers that ignore behavioral feedback loops, time lags, technological change, and indirect effects that make this a very hard-to-forecast non-linear world.

Third, the authors argue that economists often fail to appreciate how the overall environment or context can change dramatically over time. For the U.S. and many industrial countries, we live in an aging society with very little labor force growth. Real GDP potential is simply not going to be what it once was when populations were growing much faster, and no amount of fiscal or monetary stimulus is going to create the long-passed era of higher economic growth rates. For financial analysts, the regulatory shifts brought by the Dodd-Frank legislation changed the nature of how banks could or could not earn money in trading financial instruments. From demographics, to regulation, to technology, the world is a dynamic place and its ever-changing context matters in terms of how and when to apply economic models.

In sum, Blu Putnam and Erik Norland make a compelling case that economists need to take their simplifying assumptions more seriously, to embrace statistical techniques that can track dynamic markets with time-varying parameters, and to always be aware of the importance of shifts in the underlying context. And now I know why my Economics 101 course bored me to death and seemed so irrelevant to what was happening in the real world. Thanks Blu, Erik, and KT!

Endnotes

Economics Gone Astray is available on Amazon and directly from the publisher, World Scientific (WS) Professional.

Dr. Bluford Putnam is a member of both the Advisory Council and the Research Council of the J.P. Morgan Center for Commodities at the University of Colorado Denver Business School. He is also a [regular contributor to the *GCARD*] in its "Economist's Edge" section.

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Tina Reine is an Environmental Commodities Trader. She held senior level positions in carbon markets at J.P. Morgan in New York City, Cantor Fitzgerald in London, and at NextEra Energy where she received the Innovation Award for creating a new financial product. She has an M.B.A. from Columbia Business School.

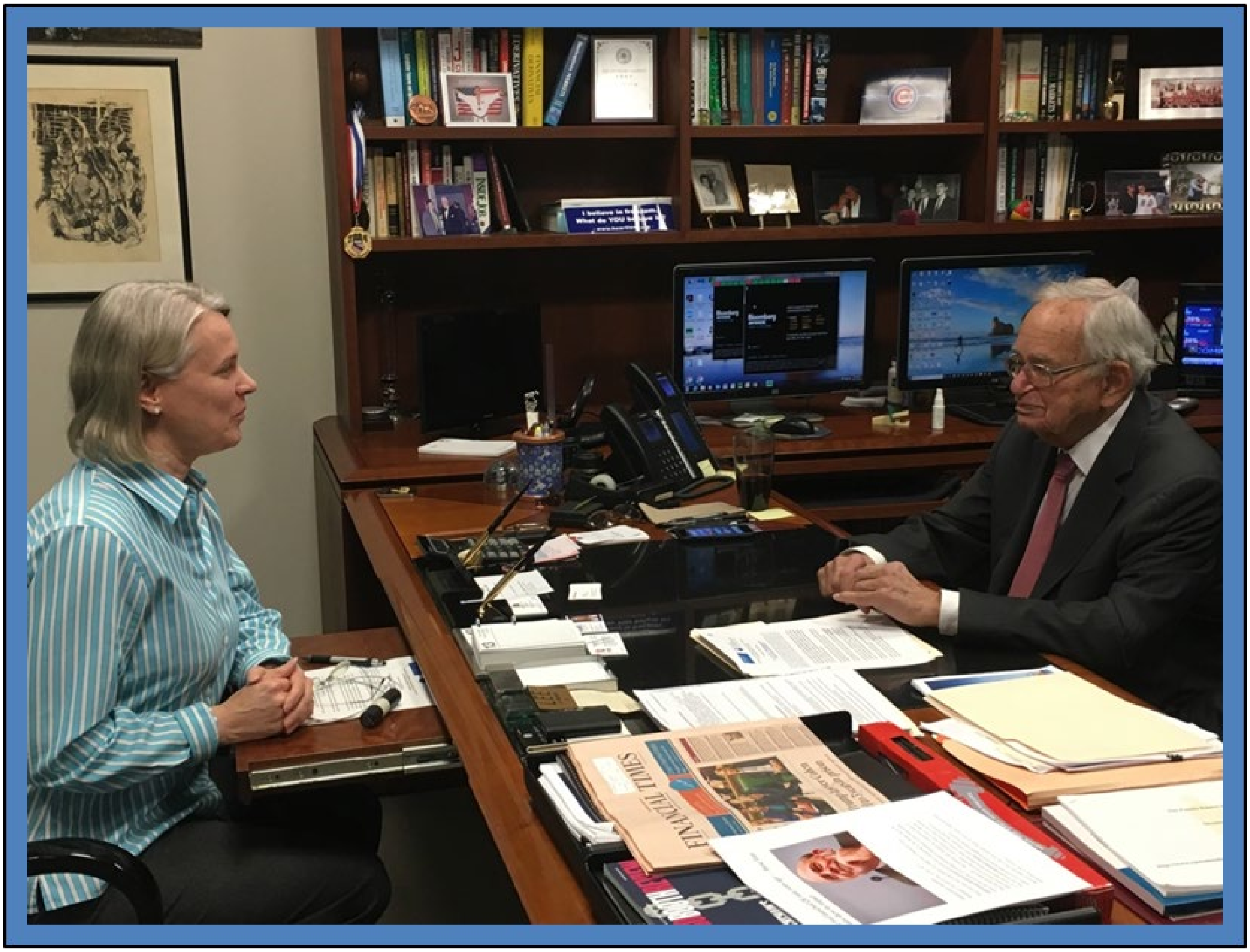
Interview with Leo Melamed

Chairman Emeritus of the CME Group and Founder of Financial Futures

Mr. Leo Melamed, Chairman Emeritus of the CME Group, in his Chicago office in December 2018. Melamed initiated the development of Globex, which was the first electronic trading system designed for futures and options trading.

In December 2018, the Contributing Editor of the *GCARD* had the honor of meeting with Leo Melamed, Chairman Emeritus of the CME Group, at his office in Chicago to discuss financial and technological innovation, past and present. Melamed was the Chairman of the Board at the CME from 1968 until 1976, after which he continued to serve in a number of board leadership positions. His significant contributions to the CME Group in specific, and to the financial industry in general, were recently recognized by CME Group Chairman and Chief Executive Officer Terry Duffy: Leo Melamed's "invention of financial futures and pioneering of electronic trading shaped the financial markets as we know them today," stated Duffy in CME Group (2018).

In our interview with the Chairman Emeritus, we focused on technological change in the financial markets. We specifically asked Melamed about the wrenching move from floor trading to electronic trading and also about his thoughts on the potential for disruptive change due to bitcoin and blockchain.



Ms. Hilary Till, Contributing Editor of the *GCARD* and Solich Scholar at the J.P. Morgan Center for Commodities at the University of Colorado Denver Business School, interviewing Chairman Emeritus Leo Melamed in December 2018.

Interview with Leo Melamed

Globex

Melamed noted that while the introduction of financial futures contracts and eventually cash settlement (rather than physical delivery) were big, groundbreaking ideas that he initiated at the Chicago Mercantile Exchange, bringing about electronic futures trading was a "huge idea."

Recalled Melamed: by 1986, "I knew that automation was happening everywhere, and it was going to capture our industry," so he began working on bringing electronic trading to the Chicago Mercantile

Exchange. "It was the hardest thing I ever worked on, harder than" establishing financial futures contracts or cash-settlement procedures, related Melamed. It wasn't until 1992 that electronic futures and options trading under the Globex system was finally launched at the Chicago Mercantile Exchange.

Because of the potential for job losses that would come with replacing open outcry trading, Melamed endured physical threats, which meant that at the time, he "had a policeman guarding … [him] and … [his] office door," recounted Melamed. "But I knew that if we didn't [provide electronic trading] …," Melamed continued, there would [eventually] be no Chicago Mercantile Exchange, no CME Group. Some other outfit in Europe or in Asia would [fill the gap] …; they didn't have an open outcry history, and they would just do electronic trades. And because of the efficiency, the cost, and the honesty that electronic [trading] provides," such characteristics would provide a brutal competitive threat to the open-outcry business model, which the Chairman Emeritus extensively covered in Melamed (2009).

"Nobody can stop the technology involved. So between all the good I saw coming out of technology, it certainly was going to capture our market so [you] either [had to] bite the bullet and take the pain or you lose the whole thing," Melamed concluded.

Bitcoin and Blockchain

Regarding recent technological innovations in the financial arena, Melamed was noncommittal on the utility of bitcoin. But "blockchain is different. That is a technology that allows you to record transactions in a much more efficient and certain way than presently. So yes, that has real strong possibilities," forecast Melamed. "But it's going to be a long time coming. It isn't something that can overwhelm" a market like electronic trading did in quickly replacing open-outcry trading floors, "but blockchain is a good technology … [that] will take some time," predicted the Chairman Emeritus.

In terms of the potential for the implementation of blockchain to obsolete various financial intermediaries, Melamed agreed that "in a way it's very scary like it was for the brokers that lost their jobs being a broker in a pit." But he concluded the interview with noting that "you are never going to stop technology; I am a big believer in, first of all, the advancement of technology and second, the embracement of technology."

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LEO MELAMED
Chairman Emeritus of the CME Group

Mr. Leo Melamed is recognized as the founder of financial futures and introduced the International Monetary Market in 1972. He has served as Chairman Emeritus of CME Group since 1997 and as a board member since 1967. He also played a leading role in the development of the CME Globex electronic trading system in 1992.

Mr. Melamed currently serves as Chairman and CEO of Melamed & Associates, a global consulting group, and as advisor to the National Futures Association, the International Advisory Council of the China Securities Regulatory Commission, and Leap Innovations. He serves on the board of overseers of the Becker Friedman Institute of the University of Chicago, and as a director of The Chicago Council on Global Affairs. Mr. Melamed is a published author of several books and the recipient of multiple awards around the world, including the Order of the Rising Sun, Gold and Silver Star, from the Government of Japan. He holds Doctor of Letters distinctions from the University of Illinois, Loyola University, DePaul University, the Tokyo-based Waseda University, and a Doctor of Humane Letters from Sacred Heart University.

EDITORIAL ADVISORY BOARD MEMBER NEWS

Blockchain and Financial Markets Innovation

Mr. John McPartland of the Federal Reserve Bank of Chicago was interviewed by **Ms. Hilary Till**, Contributing Editor of the *GCARD*, during the Canadian Association of Alternative Strategies and Assets (CAASA) conference in Montreal in November 2018. (Photo courtesy of CAASA.)

Mr. John McPartland, Senior Policy Advisor, Federal Reserve Bank of Chicago, and **Ms. Hilary Till**, the Solich Scholar at the JPMCC, participated in a fireside chat on "Blockchain and Financial Market Innovation" at the Canadian Association of Alternative Strategies and Assets (CAASA) conference in Montreal in November 2018. Mr. McPartland, in turn, co-authored an article on this topic for the current issue of the *GCARD*.

Journal of Futures Markets

Professor Isabel Figuerola-Ferretti Garrigues, Ph.D., Universidad Pontifica Comillas, Madrid, Spain, has been named to the Editorial Board of the *Journal of Futures Markets*. Dr. Figuerola-Ferretti is also an Editorial Advisory Board Member of the *GCARD* as well as a contributor to the digest.

Of note is that the Research Director of the JPMCC, Dr. Jian Yang, Ph.D., CFA, is also a member of the *Journal of Futures Markets*' Editorial Board.

Professor Isabel Figuerola-Ferretti Garrigues, Ph.D., lecturing at Universidad Pontifica Comillas, Madrid, Spain.

The Superclasses of Assets Revisited

Mr. Robert Greer, Scholar-in-Residence, J.P. Morgan Center for Commodities, University of Colorado Denver Business School and Member of the *GCARD*'s Editorial Advisory Board, was featured in "Alternative Investment News for CAIA Members" for his *GCARD* article on "The Superclasses of Assets Revisited." The CAIA Association is a professional society partner of the *GCARD*.

Mr. Robert Greer presented on commodity index investing at the University of Colorado Denver Business School's J.P. Morgan Center for Commodities (JPMCC) during the Center's Knowledge Exchange series.

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Notes

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SPECIAL FEATURE: Cutting-Edge Innovation in the Cryptosphere

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UNIVERSITY OF COLORADO DENVER

Blockchain and Financial Market Innovation

Rebecca Lewis
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Rajeev Ranjan
Senior Vice President, Citi and
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Introduction and Summary

Blockchain technology is likely to be a key source of future financial market innovation. It allows for the creation of immutable records of transactions accessible by all participants in a network. A blockchain database is made up of a number of blocks "chained" together through a reference in each block to the previous block. Each block records one or more transactions, which are essentially changes in the listed owner of assets. New blocks are added to the existing chain through a consensus mechanism in which members of the blockchain network confirm transactions as valid. The technology allows the creation of a network that is "fully peer to peer, with no trusted third party," such as a government agency or financial institution (*Economist*, 2015).

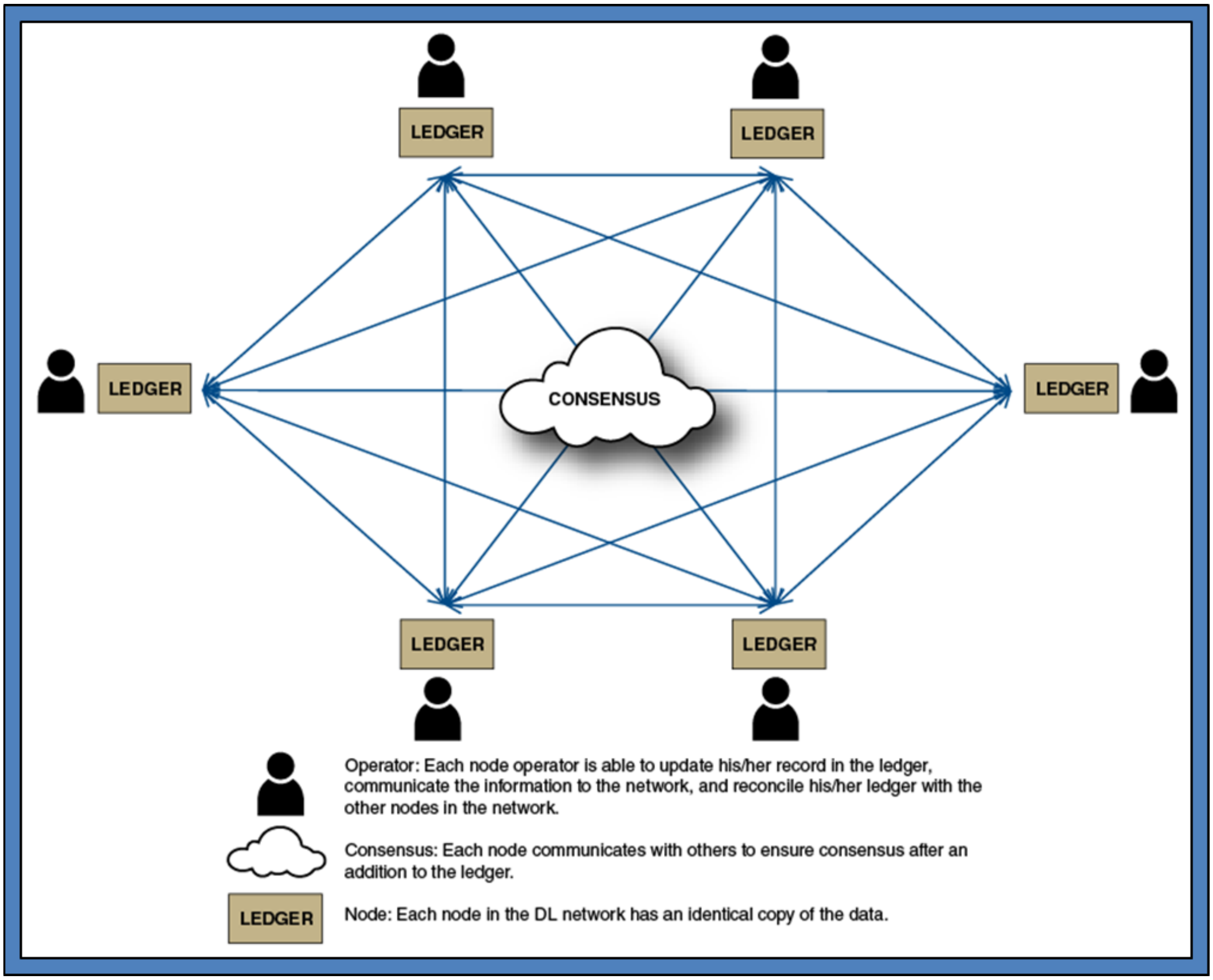
While all are in the early stages of development, there are many promising applications of blockchain technology in financial markets. The bitcoin ecosystem represents the largest implementation of blockchain technology to date (Church, 2017). Interest in the technology continues to grow in the financial technology and broader financial services communities. In this article, we provide a brief overview of what blockchain technology is, how it works, and some potential applications and challenges.

What is a Blockchain Database?

A blockchain database has a network of users, each of which stores its own copy of the data, giving rise to another term for blockchain technology: distributed ledger technology (DLT). Basic elements of a DLT network are a digital ledger, a consensus mechanism used to confirm transactions, and a network of node operators; see Figure 1 on the next page for the network setup. Generally speaking, the terms DLT and blockchain are used interchangeably in position papers and popular media though DLT is considered by some to be a more general term.

The articles in this Special Feature do not necessarily represent the views of the JPMCC, its sponsors, or donors. The articles are for educational purposes only.

Figure 1
Distributed Ledger (DL) – Setup



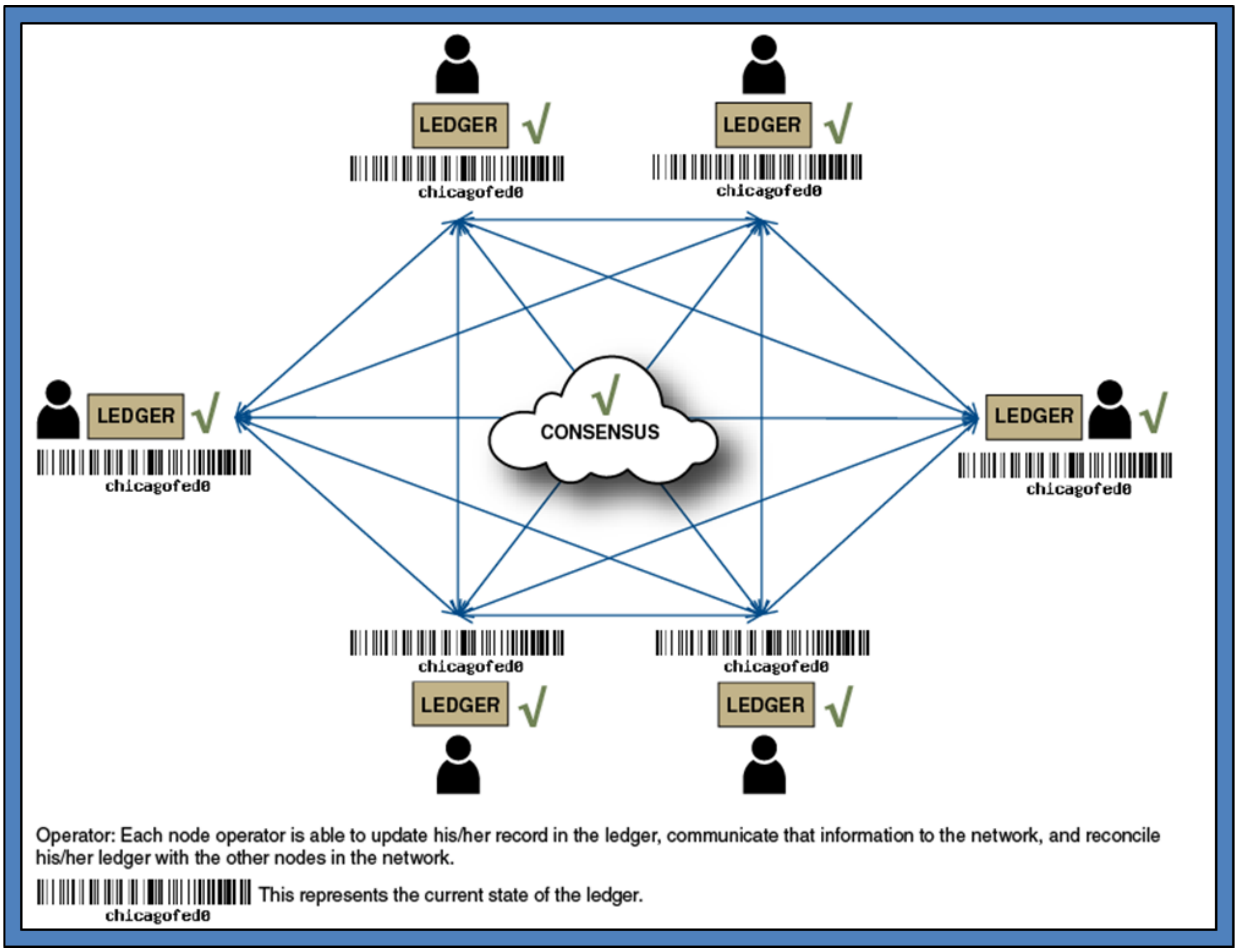
Source: Financial Markets Group, Federal Reserve Bank of Chicago.

As one industry participant involved in developing blockchain technology described it, blockchain technology is essentially a new approach to database architecture. "Fundamentally, [it is] an improvement over the way that, traditionally, databases have been designed and used in the past," noted Morgan Stanley (2016). A traditional database is a large collection of data organized for rapid search and retrieval. While there are various ways of organizing data, traditionally, the vast majority of databases have been relational, storing data in tables that users can update and search (Meunier, 2016). Relational databases are centralized, with a master copy controlled by a central authority. Users sharing a database must trust the central authority to keep the records accurate and maintain the technological infrastructure necessary to prevent data loss from equipment failure or cyberattacks. This central authority represents a single point of failure; if the central authority fails, the database is lost. Users who do not trust one another must maintain separate databases that they periodically reconcile.

How Does Blockchain Technology Work?

The key elements of a blockchain-based ledger, those that will enable future efficiency gains, are the distributed nature of the ledger, its immutable character, and the existence of an agreed-upon consensus mechanism. These make it possible to automate transactions, providing for close to real-time settlement, while maintaining strong controls against fraud. These benefits do not depend on the exact technical implementation of any given blockchain—implementations will continue to be worked out in the coming years. However, a high-level overview of how a blockchain works helps to inform discussions about potential applications of blockchain and challenges that may arise.

Figure 2
Distributed Ledger (DL) Network – All Records are Updated



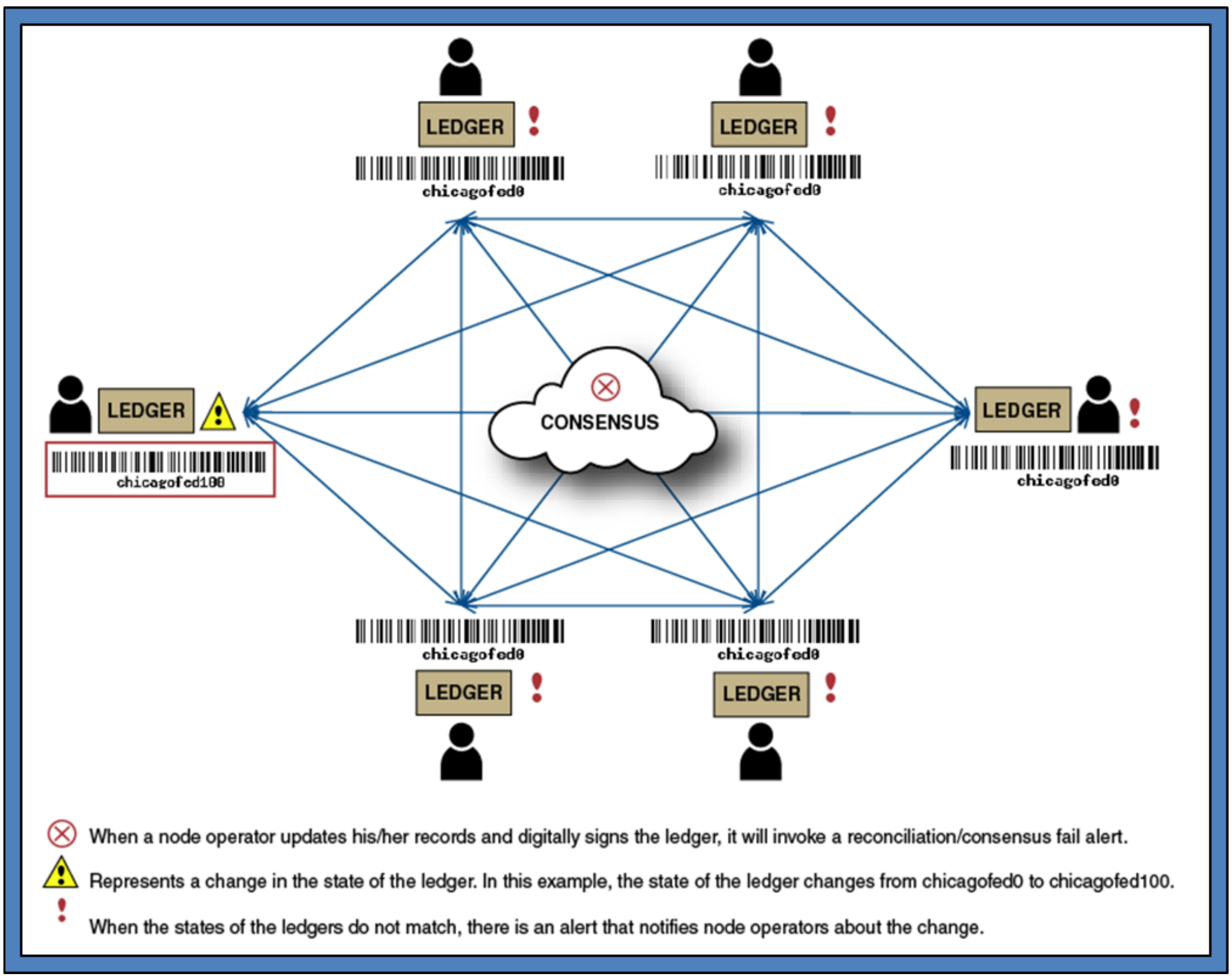
Source: Financial Markets Group, Federal Reserve Bank of Chicago.

A Simple Distributed Ledger

In its simplest form, each user can read from and write to the database, and each user's copy is updated to reflect the new state of the ledger after a transaction is confirmed through a previously agreed-upon consensus mechanism; see Figure 2 above. Once a transaction is added, it cannot be updated or deleted. In the example in Figure 2, all the node operators have the same version of the ledger ("chicagofed0"). Since all the versions of the ledgers are the same, consensus is achieved and the records are final.

When a member of a blockchain network engages in a transaction, they submit the transaction to the network; see Figure 3 below.

Figure 3
Distributed Ledger (DL) Network – New Record Added and State Changes



Source: Financial Markets Group, Federal Reserve Bank of Chicago.

The submission of the new transaction changes the state of the ledger (here to "chicagofed100"), which is now in conflict with the state of other copies of the ledger. Once the new transaction is discovered by the network, the consensus breaks, forcing other operators to either validate and update their records with the latest change or reject the new addition to the ledger.

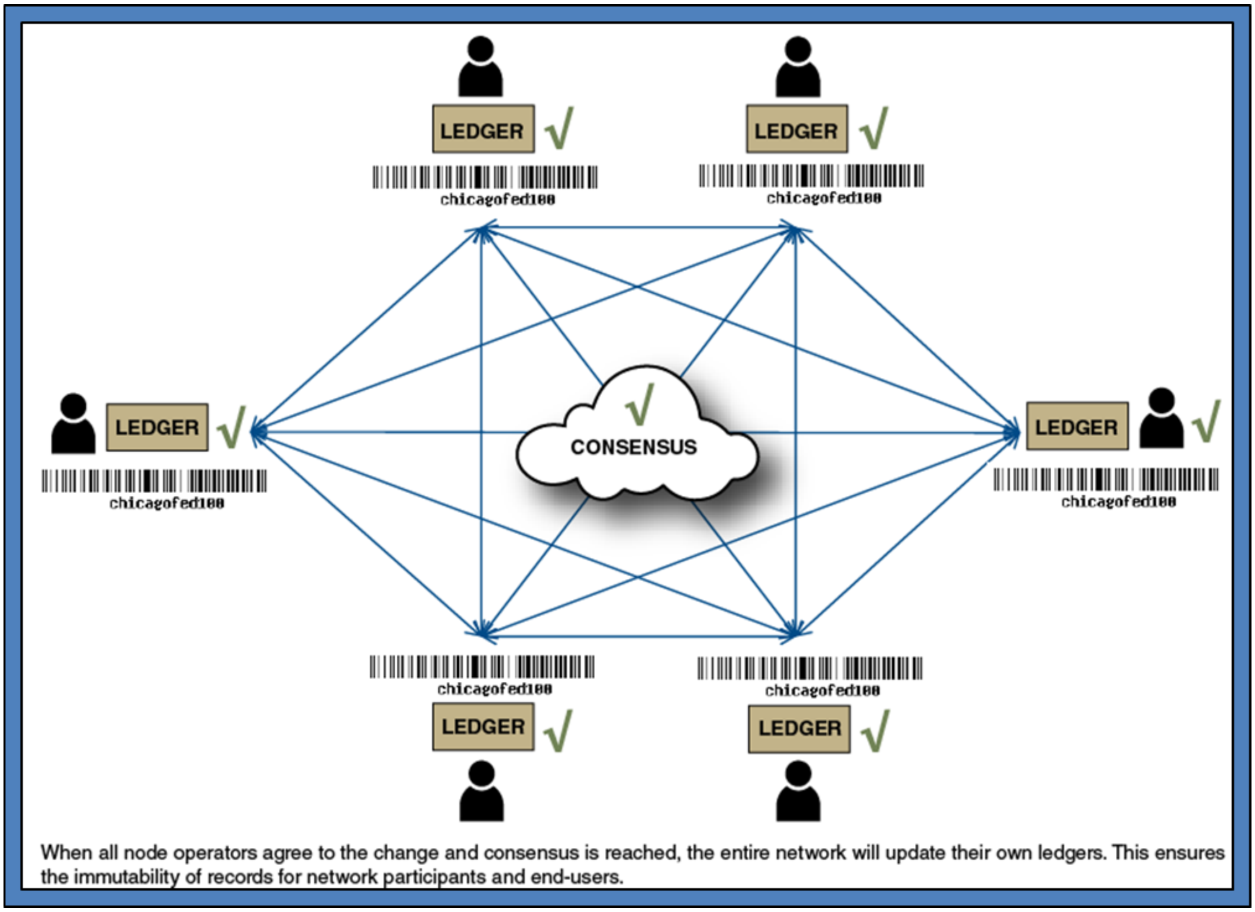
A consensus mechanism then confirms the submitted transaction as valid. There are various methods of achieving consensus on a blockchain, as we discuss below. At this point, it is simply important to understand that a blockchain database must have a mechanism through which participants agree to a change in the state of the ledger. Once consensus is achieved, all ledgers are updated to reflect the new state; see Figure 4 on the next page.

How are Transactions Added to a Blockchain?

At its most basic level, a transaction on a blockchain is simply a change in the registered owner of an asset. The process through which transactions are created and added to the blockchain is illustrated in Figure 5 on page SF7.

For person A to transfer an asset to person B, it is first necessary to determine if A is the rightful owner of that asset. This can be done by referencing past transactions in the blockchain and finding that, at some point, A received the asset and has not yet sold it. Once this is done, A and B can agree to the transaction (step 1). A block is created with the details of the new contract (step 2), and then A and B agree to the contract by adding their unique digital signatures (steps 3 and 4). Once both parties have signed the transaction, a cryptographic hash is calculated that will be used to link this new transaction to the chain of previous transactions (step 5). The cryptographic hash is a string of characters associated with a given block that is difficult to calculate but easy to verify. This makes it simple to verify a legitimate block, but difficult to engineer and insert into the chain a block recording illegitimate transactions.

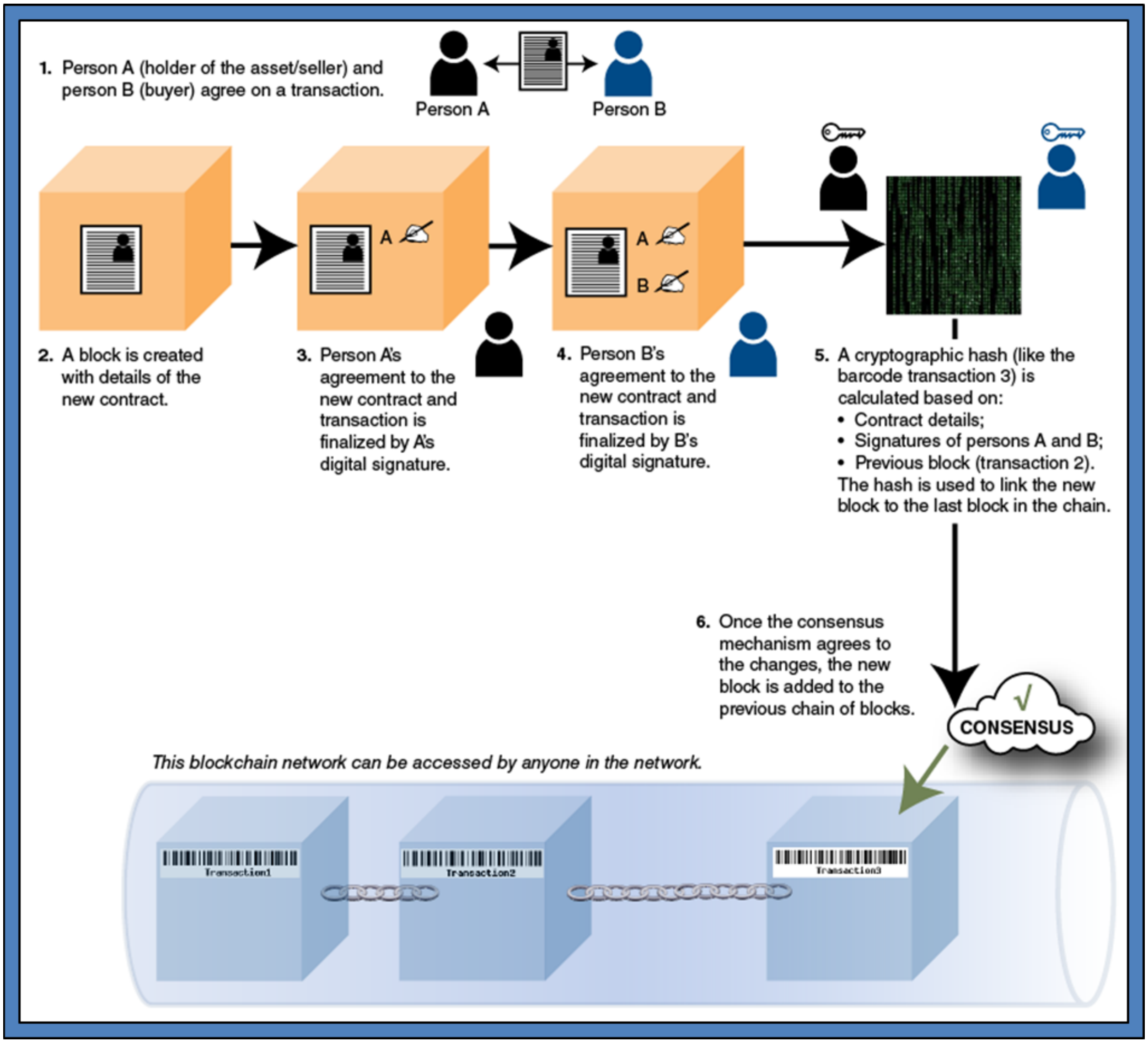
Figure 4
Distributed Ledger (DL) Network – Reconciliation and Consensus Achieved



Source: Financial Markets Group, Federal Reserve Bank of Chicago.

Next, the transaction is confirmed using the blockchain's consensus mechanism (step 6). After confirmation, the transaction is added to a block of recent transactions. This block is then "chained" to the previous blocks of transactions through a reference to the most recently created block in the chain. The updated blockchain would then be transmitted to all participants in the network so that everyone has a matching copy of the master ledger.

Figure 5
Blockchain (DL) Network – Stylized Example of a Transaction



Source: Financial Markets Group, Federal Reserve Bank of Chicago.

Permissionless Networks

Blockchain technology was first used in 2009 to implement the digital currency bitcoin. The bitcoin blockchain is an example of a public network: it is open to any user who wishes to transact, and all users can see all transactions on the blockchain. The network is also permissionless: new transactions are added to the blockchain through a cryptographic consensus mechanism requiring vast amounts of computing power to confirm transactions. The chief advantage of a permissionless network is that it does not require a central authority to confirm or deny specific transactions; individuals who do not trust one another or any single central authority can transact on the permissionless network, relying on a consensus mechanism to ensure the ledger's accuracy. This avoids the need for users to have their own database that they periodically reconcile against those of their counterparties. Instead, all transactions are recorded on a single database. Each user stores a copy of the database, so there is no single point of failure as exists with traditional relational databases. Once they are added to the blockchain transactions cannot be undone, making the ledger an immutable record of all previous transactions. Figure 6 on the next page provides an illustration of a permissionless and public blockchain network.

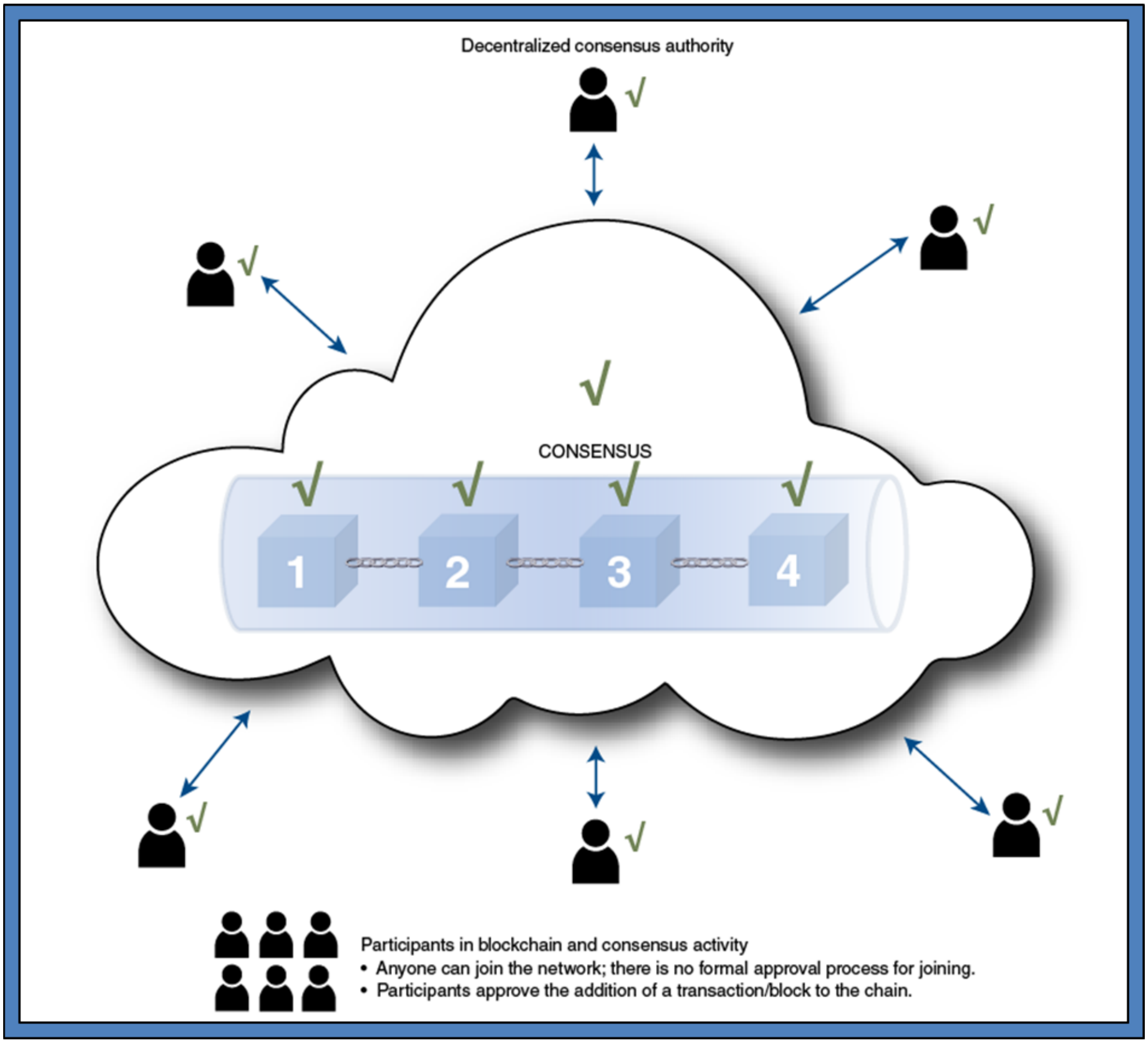
Permissioned Networks

Many see broad accessibility and a lack of a need for centralized control as two of blockchain's key benefits relative to traditional database architectures. However, for applications in financial markets where 1) there are trusted intermediaries, 2) complete transparency is not always desirable, and 3) participants must comply with regulatory requirements, this decentralized system has shortcomings. It is likely that applications of blockchain technology in financial markets will instead use private and permissioned blockchains. Private blockchains are only open to those participants that meet the membership criteria of the network, in contrast to public blockchains in which anyone is able to participate. Permissioned blockchains allow certain members to control the confirmation of transactions. These permissioning members (consensus authorities) can exert control in various ways depending upon the network design. They could be responsible for explicitly approving transactions. Another option would be to designate the permissioning members as the sole members of the network able to participate in a cryptographic consensus mechanism. Figure 7 on page SF10 provides an illustration of a permissioned and private blockchain network.

As in Kaminska (2016), some argue that a permissioned blockchain removes "a major benefit of the blockchain system: the system works between parties that do not need to trust each other. If the concept is to implement permissioned distributed ledgers between trusted [parties] … why would you use blockchain technology when more efficient alternatives are available?" However, permissioned blockchains retain many key features and benefits of permissionless blockchains, including the decentralized storage of the database and the (near) real-time reconciliation of all copies of the database. They also alleviate some of the problems posed by the permissionless system, including its need for substantial computing resources to confirm transactions.

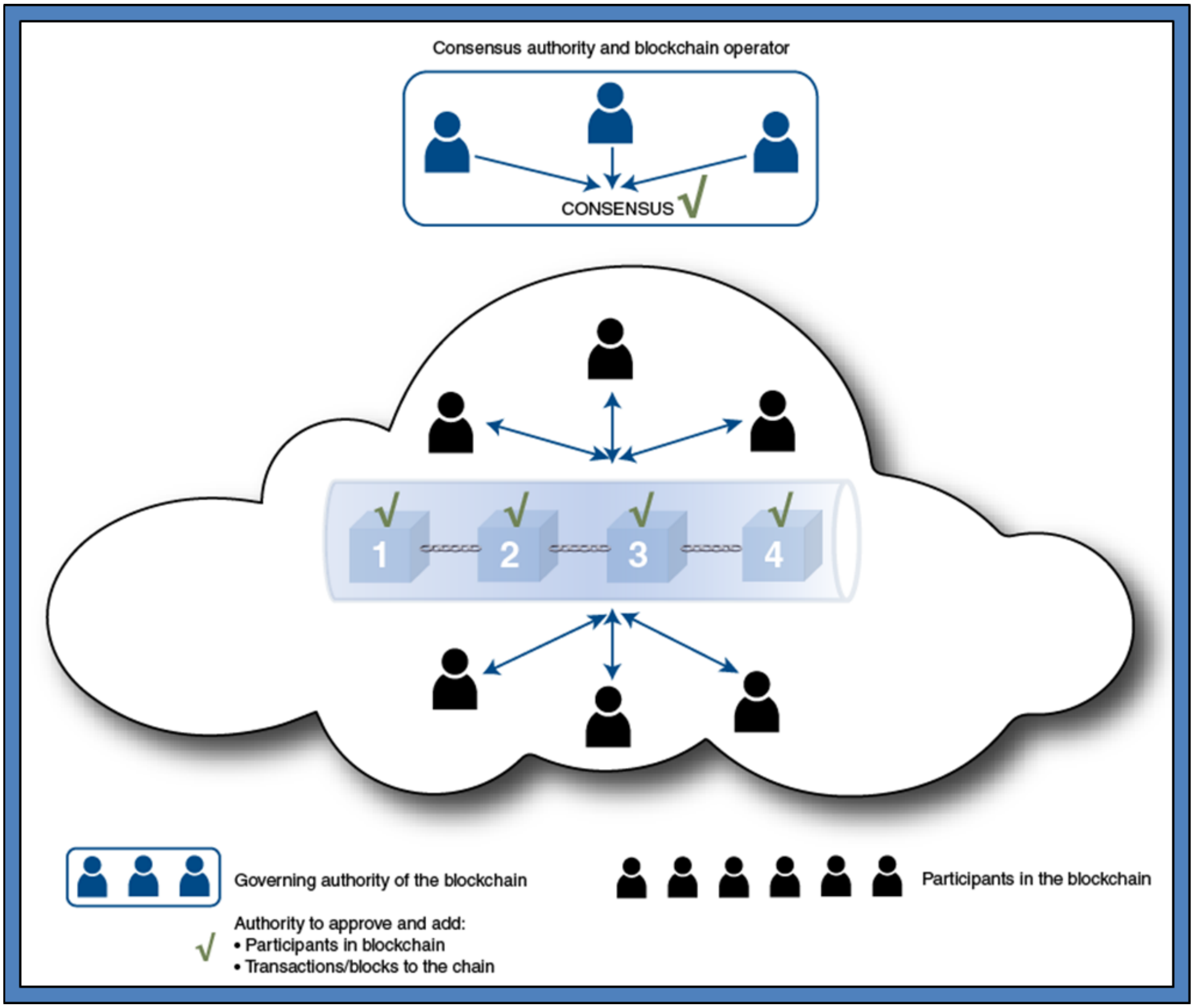
Regulatory imperatives such as Know Your Customer (KYC) and Anti-Money Laundering (AML) requirements provide further reasons to prefer permissioned blockchains for financial applications, as transactions on a fully public, permissionless blockchain are anonymous and open to all, while private systems can limit participants to those who are pre-approved and trusted.

Figure 6
Permissionless/Public Blockchain Network



Source: Financial Markets Group, Federal Reserve Bank of Chicago.

Figure 7
Permissioned/Private Blockchain Network



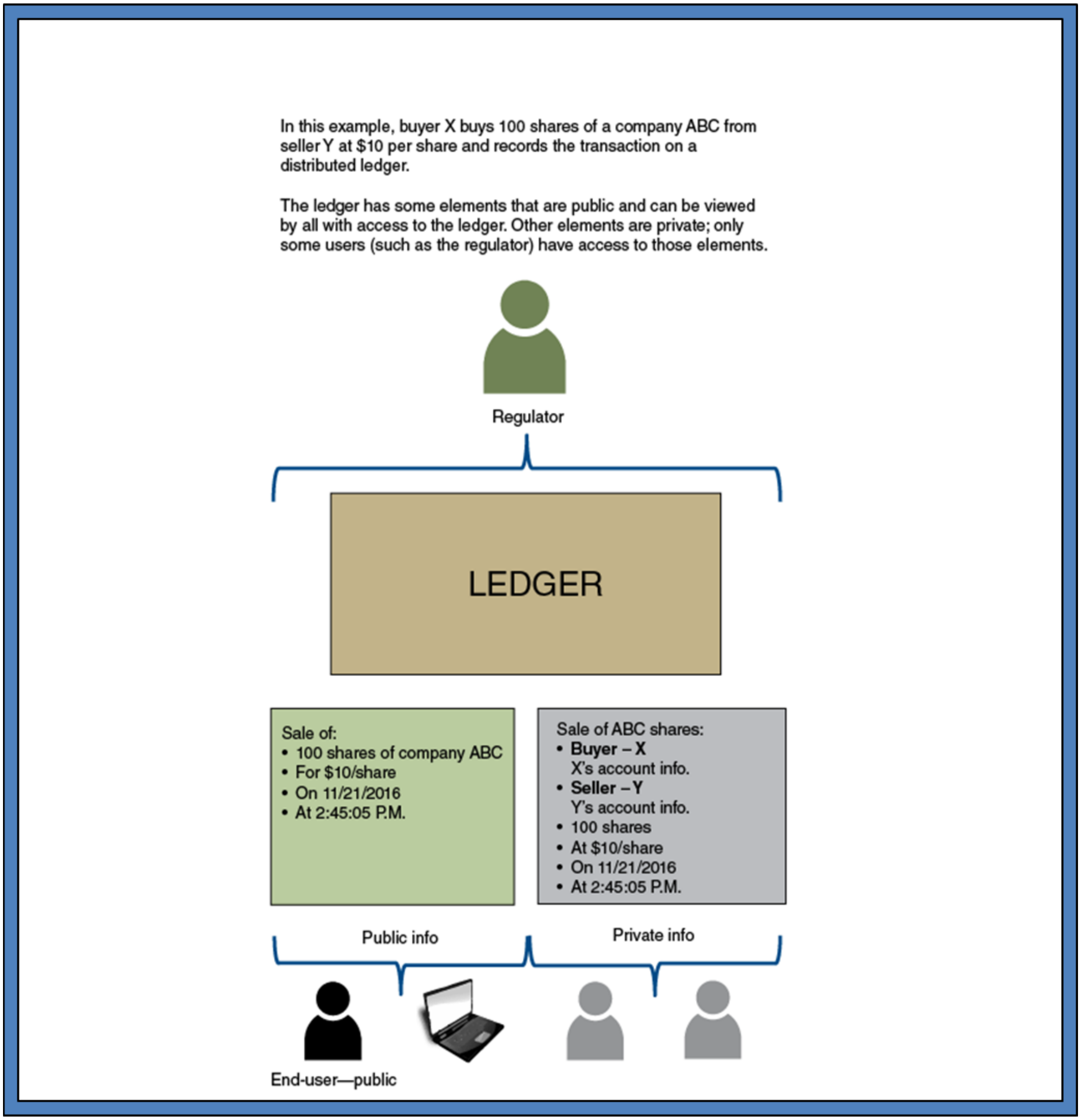
Source: Financial Markets Group, Federal Reserve Bank of Chicago.

In permissioned blockchains, it is also possible to put controls in place to allow varying levels of access to the information in the ledger. For example, regulators could be allowed to view all the details of a transaction in the ledger but not add any transactions, while users might be allowed to view selective details of the transactions depending on their access level; see Figure 8 on the next page.

Consensus Mechanism

All blockchains have a consensus mechanism that is used to add new blocks to the database. The consensus mechanism will differ depending upon the design of the blockchain, especially whether the blockchain is permissioned or permissionless. If the blockchain is permissioned, the degree to which participants in the network are willing to trust one another also has an effect on the consensus mechanism. In a permissioned blockchain, once the transaction is submitted by the two parties involved, it would then be confirmed by a permissioning member of the blockchain or by some cryptographic consensus mechanism accessible only by permissioning members. Trust in transactions is maintained because users trust the network member(s) with the power to confirm transactions.

Figure 8
Ledger Properties



Source: Financial Markets Group, Federal Reserve Bank of Chicago.

Permissionless blockchains rely on their network of participants to confirm transactions, using a variety of algorithms to ensure the validity of transactions. One implementation of a permissionless blockchain, the bitcoin blockchain, uses a Proof of Work consensus mechanism. On the bitcoin blockchain, individuals known as miners compile submitted transactions into blocks. They confirm that those spending bitcoins in each transaction received those bitcoins from some earlier transaction recorded on the blockchain and race to solve a difficult computer problem; the first miner to solve the problem confirms their block and adds it to the blockchain. The miner is awarded a certain number of bitcoins in return. Because every user on the blockchain has access to the entire ledger, users can confirm for themselves that the latest block of transactions added to the chain records valid transactions, that is, that the users spending bitcoins in the latest round of transactions received them in some earlier transaction and have not yet spent them.

A relatively automated consensus mechanism allows for the near-instantaneous update of every copy of the ledger — once a transaction is added to the blockchain, all ledgers reflect this change. There is no need for further post-trade reconciliation. The way in which blocks are added to the ledger also creates an essentially immutable database. Since blocks of transactions are chained together, the older the transaction is, the more difficult it becomes to fraudulently change it. To fraudulently change a block, an actor would have to replace that block with a new block and regenerate all of the subsequent blocks in the chain. The consensus mechanisms ensure that regenerating blocks is difficult, either due to the oversight of permissioning members or to the time and energy required to create a block (in a permissionless system.) The farther back in the chain a block is, the more difficult a change becomes because the number of blocks that an actor would have to regenerate increases. Thus, network members' confidence that a transaction will never be changed increases as the number of transactions following it increases.

Blockchain's Applications, Benefits, and Challenges

Blockchain technology has the potential to provide large efficiency gains in businesses that currently require costly intermediation, including financial services. However, any implementation will also face a number of challenges. Regulators and policymakers, including the Committee on Payments and Market Infrastructures, have been looking into both the potential applications of blockchain technology and the challenges that may arise (Bank for International Settlements, 2017).

Applications and Benefits

Possible applications of blockchain technology include:

Digital assets — Physical assets (real estate, stock certificates, gold, etc.) require a great deal of verification and examination every time they are traded, which prolongs the transaction and settlement time for each trade. DLT has the potential to transform the physical assets into a digital form for transactional and recordkeeping purposes. Such digitized assets could essentially function as online financial instruments that change hands each time the owner of the asset recorded in a ledger changes.

Digital currencies — We are already in the era of online banking, payments, and transactions, all of which are carried out with little use of physical currencies. In recent years, various forms of cryptocurrencies have been adopted for real-world transactions. Cryptocurrencies rely on encryption techniques to generate, transact, and verify their value. They operate independently of a central bank's authority and are not backed by the central bank. Some central banks around the world (for example, China, the U.K., South Africa, and the Netherlands) are experimenting with issuing digital state-sponsored fiat currencies backed by the central government.

Digital record keeping — One of the key benefits of blockchain is that it keeps an audit trail of each and every transaction and the details of the parties involved. If designed and executed well, blockchain databases will create records that are standardized, immutable, and easy for interested parties to query.

Smart contracts — In order to achieve their full potential, implementations of blockchain technology will likely be accompanied by smart contracts. Smart contracts are legal contracts written in computer code that execute automatically once certain conditions, specified in the contract, are fulfilled. Smart contracts can be added to distributed ledgers to self-execute on the basis of information in the ledger. This will allow for the automation of processes that currently require manual interventions.

Benefits that may arise from the use of blockchain technology include:

Reduction in settlement period (post-trade) — Settlement periods (the time between the execution of a trade and the performance of all duties necessary to satisfy all parties' obligations) can be drastically reduced with the swift record of submissions and their confirmation on a blockchain. This may foster greater liquidity in certain types of trades that currently face lengthy settlement cycles and may promote better capital usage. At present, the title to most financial assets can only be settled against payment when banks are open for business. If there were one blockchain that accounted for the ownership of money and another that accounted for the ownership of securities, then, assuming that buyers had sufficient funds and sellers had sufficient shares, a settlement versus payment of funds could occur at any time on any date in a matter of seconds, with legal finality and certainty.

Faster payments—Global payments systems require multiple regulatory checks and lengthy settlement cycles. The foreign exchange industry is one of the most intermediated markets in the world, requiring settlement banks and commercial banks to facilitate movement of currencies. A DLT service with digital identities for the parties involved in a trade could be used to shorten settlement times.

Challenges

The challenges posed by blockchain technology fall into two broad categories: technical and business; and regulatory.

Technical and business challenges

Achieving consensus — There is a need for consensus among a blockchain network's members. Since the ledger is distributed among all participants in the blockchain, any protocol changes must be approved by all. A potential solution, possible in a permissioned network, would be to allow one or a few participants the authority to make protocol changes that were binding upon the entire network. This, however, requires significant trust in the authorized participants.

Standardization — There is also a lack of standardization of blockchain network designs, which can cause major issues in their implementation and acceptance by businesses. Many national and international organizations are trying to establish generally accepted technical standards.

Interoperability — Current businesses will face challenges related to interoperability of blockchain platforms with their existing internal systems. Externally, it remains to be seen how blockchains from multiple businesses might operate with each other.

Scalability — The need to increase the scale of distributed ledger systems also represents a challenge, especially for permissionless blockchains that use a race to solve a computer problem in order to confirm a transaction. The race takes a large amount of computing power, limiting the speed with which new transactions can be confirmed. All networks, permissioned or permissionless, will require a large amount of storage resources, as each node in the network will maintain its own copy of the distributed ledger.

Efficiency — There will be trade-offs between the efficiency of a blockchain and its ability to avoid relying on trusted parties. A complex computational system to confirm transactions is less efficient than a system more reliant on the discretion of permissioning nodes in the network but offers the advantage of not needing everyone in the network to agree to trust certain parties.

Immutability — Once added to the blockchain, a transaction is permanent. "Fat-finger" trades, or trades that regulators demand be reversed, can only be changed by submitting an equal and offsetting trade, which the parties involved in the original trade will both need to accept.

Legal uncertainty — Currently, firms do not have clarity over the laws and regulations that will apply to DLT implementations in cases of fraud, bankruptcy, and other failure scenarios. This is especially a problem for firms that operate in multiple jurisdictions.

Security — While the reduced reliance on a central authority and the fact that copies of the ledger are stored in more than one place ameliorate the single point of failure problem present in many legacy systems, blockchain's distributed nature also creates security concerns. The more participants in the network, the more points of attack there are for cybercriminals to target. If cybercriminals are able to steal the information of a user necessary to submit a trade, they could create fraudulent, and immutable, transactions.

Liquidity — The use of a blockchain for title transfers could drastically reduce the risk associated with current settlement conventions, but it will increase the importance of liquidity; funds and assets must be in proper form and location for such expedited settlement.

Privacy — Blockchain's potential impact on the confidentiality and speed of information transfer about record changes may also be of concern to some users. For example, in finance, the acquisition and analysis of data are key to a firm's competitive advantage. Some firms may be reluctant to participate in a shared database in case of information leakage that could cost the firm's business.

Intellectual property — Blockchain technology may be subject to legal challenges and costs that could impede innovation. Industry participants involved in blockchain research are increasingly patenting blockchain-related technologies; the number of blockchain-related patents filed doubled between January and November 2016 (Kharif, 2016). The patents could make firms working with blockchain technologies vulnerable to legal challenges and prevent new firms from entering the market.

Regulatory challenges

Uncertainty — There is currently uncertainty over rules across various regulatory agencies. Existing regulations may be major hurdles for DLTs. To enable innovation, regulatory agencies should work alongside DLT firms as they test new products and services.

Currency control — Central banks will have to find ways to maintain control over digitized currencies. If central banks were to allow commercial banks to place money in special accounts and then digitize the money on the bank's blockchain, regulators would need a mechanism for overseeing its use and ensuring that the digital currency issued did not exceed the amount held as central bank reserves.

Conclusion

While much work remains to be done, blockchain represents a promising source of future innovation in financial markets. DLT technology possesses the capability to improve the efficiency and security of financial markets, provided it is implemented in the right way. In the near future, we will see the development of specific applications of DLT that are likely to enable better cooperation between the public sector and private sector and improve transparency, trust, information sharing, and audit trails.

Endnote

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Ms. Rebecca Lewis is currently a student at Yale Law School. She was a financial markets analyst at the Federal Reserve Bank of Chicago from 2016 to 2018 where she researched public policy issues relating to financial market infrastructures and central counterparty risk management. She graduated from Williams College in 2016 with a degree in Economics.

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Mr. John McPartland is a senior policy advisor in the economic research department. He advises senior management of the Federal Reserve Bank of Chicago on matters involving international netting systems, settlement systems for fixed income and equity securities in G-5 countries, exchange-traded derivatives, privately negotiated derivatives, risk mitigation techniques, especially bilateral collateralization of foreign exchange and derivatives instruments, margining systems of derivatives exchanges in G-10 countries, idiosyncrasies affecting U.S. securities markets, payment initiatives and issues relevant to collateralizing or clearing over-the-counter (OTC) derivatives instruments or issues raised by high frequency trading. Mr. McPartland also contributes to the Federal Reserve's position on public policy issues involving netting systems, supervisory oversight of exchange-traded and OTC derivatives, international competitiveness and the appropriate regulatory structure of domestic financial markets. He serves as a technical expertise resource that can be seconded to other national authorities.

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Mr. Rajeev Ranjan is a Senior Vice President at Citi, managing operational risk for electronic trading for global Citi businesses. His research interests include risk management, market-microstructure, algorithmic trading, exchange-traded derivatives, financial market infrastructures and fintech. Prior to Citi, Mr. Ranjan was a policy advisor and business economist in the economic research department at the Federal Reserve Bank of Chicago where he contributed to the Federal Reserve's position on public policy issues involving financial markets. Prior to joining the Fed, Rajeev worked for G H Financials and DV Trading in various capacities as an algorithmic trader, programmer and quantitative researcher. Mr. Ranjan received his Bachelor's degree in Information and Communication Technology from DA-IICT in India, a Master's degree in Finance from Illinois Institute of Technology and an M.B.A in Economics and Finance from University of Chicago's Booth School of Business.

Three Possible Ways that Blockchain Technology Could Disrupt the Commodities Industry

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Luis Quintero
Co-Founder and Managing Director, New Beacon Partners

Introduction

Today we are seeing wide-ranging applications for blockchain technology. From digital payments, to streamlining supply-chains, to the security of votes in elections, each day new applications and real-world use-cases for blockchain technology are being introduced and proposed.

In terms of the commodities sector, blockchain technology has many practical applications that are not hypothetical but rather are possible using technology that exists today. Specifically, blockchain technology can be incorporated into (a) the current United States crop insurance industry, (b) supply chain logistics to help increase food safety and minimize the cost of food recalls, and (c) a new mechanism through which investors can gain direct exposure to commodities and commodity producing assets. In this paper we will investigate these three applications and discuss how the incorporation of blockchain could improve on the status quo.

What is Blockchain Technology?

Blockchain technology provides a way for untrusted or unaffiliated parties to transact using a common shared ledger or record of transactions. The technology can be applied to a variety of "transactions," including payments for goods, votes in an election, and updates to medical records, for example. Additionally, this particular type of technology allows two parties to transact without relying on an intermediary thereby potentially reducing the cost and time of business operations as well as providing the potential for greater operational efficiency.

What is a Smart Contract?

In many cases, we expect blockchain technology to be applied via smart contracts. A smart contract is custom computer code stored on a blockchain and executed by a blockchain network. The blockchain network independently facilitates the verification and enforcement of the contract as well as enabling individuals to track the contract in real-time. In some cases, smart contracts have what is known as a "triggering event." A triggering event is typically a binary outcome whose occurrence can be verified by an independent third-party. In most cases, the contract has a payout associated with the triggering event.

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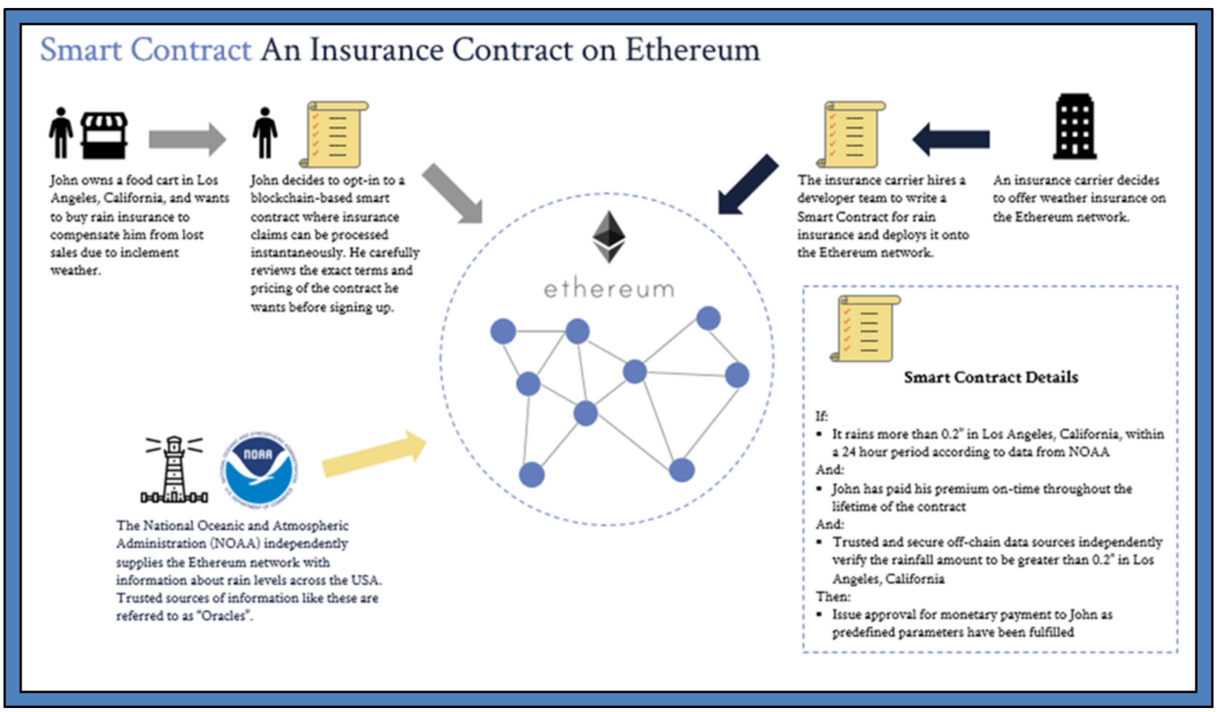
For example, John, a food-cart vendor in Los Angeles, California, could enter into a smart contract with an insurance carrier to insure against inclement weather. In this case, the smart contract would specify the location and specific amount of rain that would have to fall in order to trigger the insurance payout from the carrier to John. John would pay the carrier a monthly premium for this contract and the carrier would place the insurance payout into an escrow account. John and the carrier would specify an independent third-party to act as the trusted-information source. In this case they could select the National Oceanic and Atmospheric Administration (NOAA) as the source for daily rainfall information by specific location. Each day the smart contract automatically checks the NOAA weather database for rain in Los Angeles, California. If one day it rains more than the agreed upon amount, in this example 0.2 inches, and if John had been paying his premium on-time throughout the life of the contract, then the insurance claim would immediately and automatically be paid out to John.

John benefits from entering into the smart contract because unlike a traditional insurance contract the payout is immediate and automatic. He does not need to "trust" the insurance carrier to follow through with his claim or wait out the insurance claim process, which could potentially cause disruptions to his operations. The insurance carrier could also potentially experience significant cost savings for a smart contract policy compared to a traditional policy as much of the administrative work is automated. Additionally, smart contracts could provide insurance carriers with another type of insurance product to sell to their clients. This hypothetical scenario is illustrated in Figure 1 below.

Figure 1
Simplified Smart Contract Example



Source: New Beacon Partners.
Note: Icons courtesy of FlatIcon.

Smart Contracts and the United States Crop Insurance Industry

We can extend the example of John and the insurance carrier to the United States crop insurance industry. Currently, there are two types of crop insurance available to farmers in the United States: Crop-Hail and Multiple Peril Crop Insurance (MPCI). Crop-Hail policies are not part of the Federal Crop Insurance Program and are provided directly to farmers by private insurers. Many farmers choose to purchase Crop-Hail insurance as hail has the unique ability to destroy a significant portion of a farmer's crops while leaving the rest undamaged. In areas of the United States where hail is frequent, farmers often purchase a Crop-Hail policy to protect their high-yield crops. Unlike MPCI policies, a Crop-Hail policy can be purchased at any time during the growing season, according to National Crop Insurance Services.

MPCI policies differ from Crop-Hail policies in that they must be purchased prior to planting and cover loss of crop yields from a number of natural causes including drought, freezing temperatures, disease and excessive moisture. Under the Federal Crop Insurance Program there are currently 15 private companies that are authorized by the United States Department of Agriculture Risk Management Agency (USDA RMA) to write MPCI policies. The USDA RMA oversees and regulates the program as well as sets the rates that can be charged and determines the crops eligible to be insured in different parts of the country. The federal government subsidizes the farmer-paid premiums to reduce the cost for farmers and provides reimbursement to the private insurance companies to offset a portion of the operating and administrative costs. These subsidies ensure that crop insurance remains affordable to the majority of farmers and ranchers, again according to National Crop Insurance Services.

In the insurance industry, one type of insurance, parametric, should be well suited for use with smart contracts. Parametric insurance (also known as index-based insurance) compensates a policyholder when agreed-upon parameters are met. It is essentially an if-then contract for insurance. Payment is tied to predefined parameters, thereby decoupling the insurance policy from an underlying asset. Therefore, parametric insurance differs from traditional insurance because it does not indemnify the actual loss incurred to an asset from a risk-event. In a parametric insurance contract, the insurer makes an agreed-upon monetary payment based on when predefined parameters are met, which makes the payout process predictable and quick (Foggan and Cwiertny, 2018).

Since the crop insurance is based on verifiable data (i.e., weather data), the United States crop insurance market is a suitable candidate for smart contracts. Since Crop-Hail policies are already provided directly to farmers by private insurers instead of through a government program like MPCI policies, Crop-Hail policies represent a better candidate for potential smart contract implementation. Similar to our example of John and the insurance carrier, farmers would be able to enter into smart contracts with private insurers. In this case, the smart contract would work as follows:

1. The farmer and the private insurer would agree to terms of the Crop-Hail policy as they do today; however, the terms of the contract would then be coded onto a blockchain.

2. In the event that hail does occur and is greater than the size defined in the parameters of the contract, the smart contract would automatically verify the hail event with an independent third-party, in this case most likely the NOAA.

3. Once the hail event was confirmed, the farmer would automatically and immediately receive a payout from the private insurer.

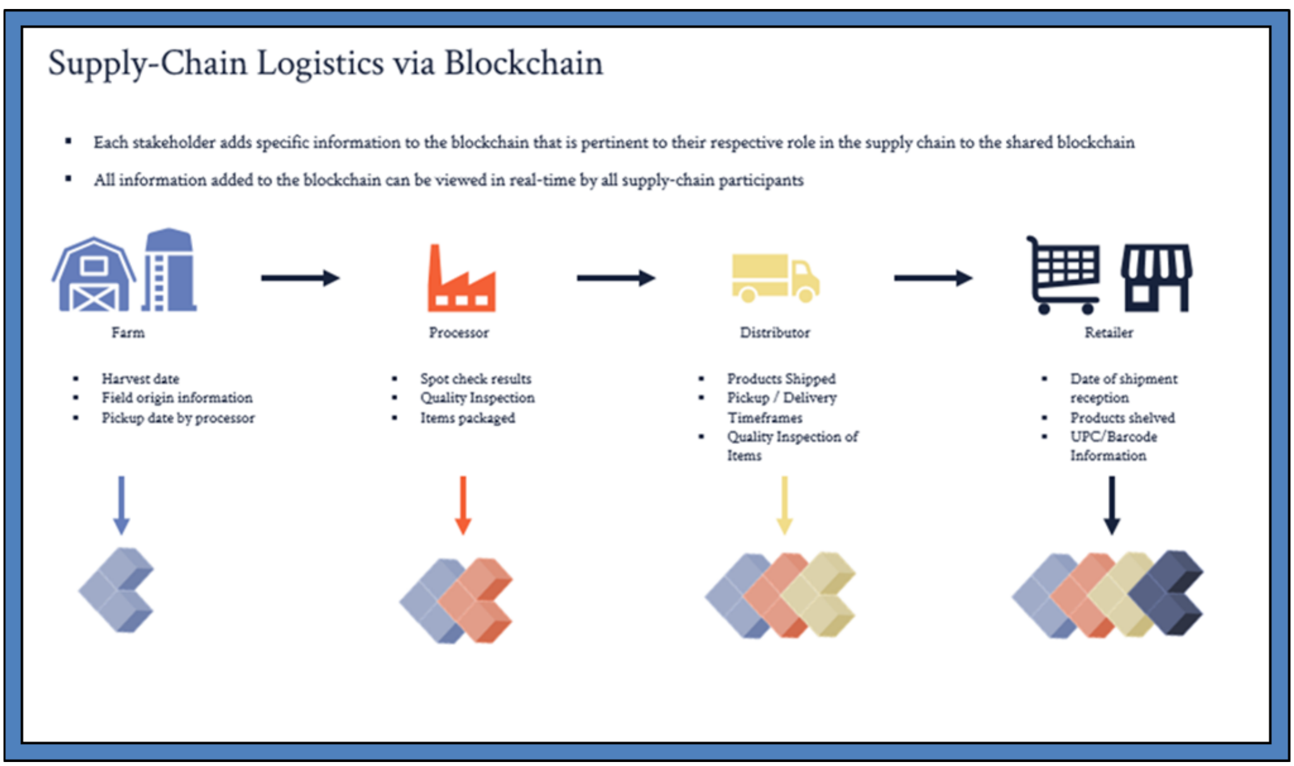
There could be several major impacts from the integration of smart contracts into the crop insurance market, both for the farmer and the private insurers. First, farmers would receive immediate and automatic payouts, meaning that once the event was verified, they would be compensated. Second, since the insurance contract is decoupled from the underlying asset, there would be no need for an insurer to send an adjuster to the farmer's field to examine the damage or even for the farmer to have to report the damage himself or herself to the insurance company (Martin, 2018). Instead, trusted and secure off-chain data sources and indices could be monitored to capture information on the contract parameters and provide approval for automatic payout when the contract parameter is met or exceeded (Foggan and Cwiertny, 2018). Third, enabling farmers to purchase Crop-Hail insurance policies via smart contracts could increase the potential for competition among insurers. Increasing competition among insurers may then lead to decreases in premiums for farmers. Fourth, by implementing Crop-Hail policies via smart contracts a significant cost savings could be experienced by the private insurer, assuming many of the administrative costs of maintaining and monitoring the contract were alleviated, a portion of this cost would presumably be transferred to the farmers in the form of lower premiums. Finally, there would be less room for fraud. Since the information needed for the contracts would be provided by an independent third-party, there could also be less of a chance for the information source to be manipulated.

Minimizing Costs and Impacts from Food Recalls

Every year 48 million Americans are made ill by food-borne pathogens (Kowitt, 2016), and the average impact to an affected food company is typically $10 million in direct costs (Tyco Integrated Security, 2012) such as notification (to regulatory bodies, supply chain and consumers), product retrieval, storage, destruction of the unsalable product as well as additional labor costs associated with these actions, and all of this is before factoring in brand damage and lost sales. Additionally, the current method with which food companies handle food recalls seems to us inefficient given the technology available. For example, companies release the product name, product code numbers, UPC codes as well as expiration dates and product descriptions to suppliers and customers to try to contain contaminated items. Even if the food company can pinpoint that one particular field or factory as responsible for the contamination, current technology takes more than 6 days to trace back a particular piece of fruit to its farm of origin. If a food company were to utilize blockchain technology to capture supply chain and transportation information this trace-back process is decreased from more than 6 days to less than 2.5 seconds (Walmart, 2017). Furthermore, food companies can also pinpoint where particular items went very quickly. For example, if they knew food items from "Factory X" were contaminated they could instantaneously determine what stores these affected items were shipped to, when they were received and contact the stores to have those items immediately pulled from shelves, and potentially contact customers who purchased that product. This would prevent mass panic over a potential food recall as well as the destruction of unaffected products, associated labor costs as well as mitigate brand impacts from the recall. The advantage of decreasing the trace-back process time cannot be understated for food companies that are trying to trace and mitigate the risks of food recalls to the public. Major corporations are beginning to implement this technology into their supply chains for this exact reason. Walmart has been working with IBM on a food-safety blockchain solution and is now requiring all of its leafy green suppliers to upload their data onto the blockchain by September 2019 (Walmart, 2018).

Blockchain technology would enable food companies to quickly and accurately contain food contamination events. Figure 2 below illustrates how blockchain technology could be utilized to capture data from each stakeholder, thereby allowing the data to be quickly accessed during a recall or trace-back scenario. By being able to trace back food from store to origin in less than 2.5 seconds compared to 6 days, they will be better able to minimize the number of individuals affected as well as in some cases prevent the contaminated items from ever being shelved. Additionally, by being able to determine which stores received contaminated items via their supply chain history, unaffected food items could be sold without generating additional food waste and lost revenue to the food company. Furthermore, consumers would be given a greater sense of confidence that the recall was effective as the technology can empirically show that the infected food items have all been accounted for.

Figure 2
Supply Chain Logistics via Blockchain



Source: New Beacon Partners.
Note: Icons courtesy of Microsoft PowerPoint.

A New Potential Way for Investors to Gain Direct Exposure to Commodities

When an investor decides he or she wants to allocate a portion of his or her portfolio to commodities they typically are faced with the following 5 ways to gain exposure: 1) Directly purchasing the commodity, 2) Use commodity futures contracts to gain exposure, 3) Subscribe to a commodity-focused private placement fund, 4) Buy shares of exchange-traded funds that specialize in commodities or 5) Buy shares of stock in companies that produce commodities.

The most direct way to gain exposure is the first option, to purchase the commodity outright; however, in order to do so an investor would generally need to accept physical ownership of the commodity and store it. Some commodities like precious metals have developed markets for buying a bar or a coin, and these are fairly easy to store; however, what if an investor wants to invest in crude oil or natural gas? In today's markets direct ownership of crude oil, natural gas, or other hard-to-store and hard-to-divide assets is extremely difficult and in some cases not possible for a typical retail investor; however, with blockchain, we argue this becomes possible.

In July, blockchain platform Maecenas partnered with London gallery Dadiani Fine Art to offer fractional stakes in Andy Warhol's *14 Small Electric Chairs (1980)*. 31.5% of the Warhol work was offered for sale via cryptocurrencies and the minority shares were distributed to winning bidders paying in cryptocurrencies. The sale and subsequent trading of these minority shares are tracked via blockchain and effectively create a transparent and real-time marketplace for the artwork (Randall-Stevens, 2018).

This model of "tokenization" can be applied to many types of asset classes outside of art and has already been employed in real estate. In 2018, the St. Regis hotel in Aspen sold 18.9% of the resort for $18 million via digital tokens (Carroll, 2018). This sale enabled investors to gain direct exposure to a real estate asset, that without tokenization, they would never have been able to hold in their portfolio.

Like the St. Regis hotel in Aspen, this model of "tokenization" could be specifically applied to hard-to-store and hard-to-divide assets and potentially introduce both a new type of product to the commodities market as well as a new type of product provider. Currently, the majority of Exchange Traded Funds (ETFs) and Exchange Traded Notes (ETNs) that provide exposure to hard-to-divide or hard-to-store commodities such as crude oil and natural gas by holding futures contracts and not the actual physical asset. This could change with the utilization of blockchain technology by ETF and ETN managers as these managers could warehouse hard-to-divide or hard-to-store commodities using traditional storage methods and digitally "divide" them into tradeable tokens. Like the Warhol painting, blockchain technology could allow an asset typically only owned by one buyer to be owned by many. This additional liquidity could potentially provide an incentive for managers to begin to offer this type of a product.

Using blockchain technology would not avoid other costs such as transportation, storage, insurance or enforcement-of-contract legal fees; however, it would enable investors to obtain direct exposure to commodities without having to invest through a traditional ETF or ETN. Blockchain technology could enable fund companies to expand their offerings to investors, thereby allowing investors to obtain direct exposure to a particular asset in fractional amounts and without having to take delivery of the particular asset.

Additionally, the "tokenization" model could be applied to locations where commodities are mined, drilled or produced. For example, an owner of a gold mine, oil field or farm could digitally "divide" their mine, field or farm and sell a percentage of their commodity producing asset via digital tokens, just as the St. Regis hotel did in Aspen. By selling a percentage of their mine, field or farm via digital tokens, the owner could experience a monetization event while providing investors direct access to a commodity producing asset that would typically only be available to them indirectly through an ETF or ETN. In this particular case, the owner of the mine, field or farm would continue to operate the asset while the owners of the digital token would share in the profit / loss of the commodity producing asset.

By applying the tokenization model, a new type of commodities-linked product could be created and begin to give investors a greater degree of flexibility as well as opportunity to invest directly in commodities and commodity producing assets.

Conclusion

In the above discussion, we noted our belief that blockchain technology can bring positive change to the commodities industry; however, what is most important is that it is possible to implement this technology today. The applications discussed above are not unsubstantiated or purely speculative applications, but rather are applications that either are already being implemented or have a clear path towards implementation. Blockchain technology should not be thought of as a strange or obscure technology but instead as the next technological innovation capable of creating better and more secure ways to transact goods and services. Just as the internet revolutionized the way that market participants interacted, we argue that blockchain too will similarly impact the status quo.

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Digital Assets: The Era of Tokenized Securities

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Introduction

The advent of bitcoin and other cryptocurrencies have recently pushed the topic of digital assets to the forefront of many conversations in finance and technology. It is our belief that these assets stand as an effective fundraising mechanism, enable access to global investor pools, unlock liquidity in many assets, and represent an opportunity for regulators to be proactive in compliance. Perhaps what is not widely appreciated is that these assets have actually been prevalent for over a decade and have had an impact in a variety of industries.

Digital assets initially included everything from pictures, video, news media, and music. The emergence of the internet marked the first time these digital asset files could be shared peer-to-peer over the web. What happened that was so threatening to established industry players is that the sharing of these files and assets, particularly music, was facilitated through copying and replicating, effectively crippling their value on the market by removing their scarcity. This led to disruptive new business models like Napster, large regulatory involvement from the U.S. Federal Communications Commission, and the creation of digital copyright laws to attempt to protect the incumbents. The companies that succeeded during these early beginnings included those that successfully utilized technology to master the distribution of these assets. YouTube and Netflix enabled consumers to stream content from their homes instead of going to the video rental store, Instagram and Snapchat have allowed people to share pictures with friends globally and instantaneously without having to get the images developed, while Facebook, Yahoo!, and Twitter have aggregated news content from different sources in one easily accessible location bypassing traditional media sources.

While digital assets were absolutely transformative for these other mediums, currency and money never quite experienced a positive relationship because as most people hopefully know, money shouldn't be copied and shared. That's counterfeit. As a result, many of the earliest forms of internet money or digital cash did not survive. That did not mean that money and value transfer could not benefit from the fungibility, or how easily tradable digital assets are, someone just had to figure out how this money could not be spent twice.

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Bitcoin and the Double-Spend Problem

In 2008, in response to the financial crisis, an anonymous author (or authors) with the pseudonym of Satoshi Nakamoto published a white paper titled, "Bitcoin: A Peer-to-Peer Electronic Cash System." The paper was groundbreaking because through a combination of cryptography and mathematics, an effective solution was proposed to solve the double-spend problem. Essentially, the ideas ensured digital money or value traded over networks could maintain their worth. Since then, blockchain, its underlying technology, has slowly become the platform where digital tokens or assets could be created and programmed to represent the value of anything from currency, commodities, common shares, and real estate. These assets could then (potentially) benefit from digital distribution, built-in compliance, global investors, 24/7 trading, and be traded instantaneously between peers.

Ethereum and Initial Coin Offerings

In 2014, a 19-year old student from the University of Waterloo (Canada), Vitalik Buterin, received the opportunity of a lifetime. Buterin was obsessed with Bitcoin, but saw several key limitations to its effectiveness as anything beyond currency or a store of value. Buterin sought to create the underpinnings of a new economic system, Ethereum, where complex financial transactions could be built, programmed, and autonomously executed according to a set of coded conditions. Peter Thiel, founder of PayPal and early investor in Facebook, saw the potential of this system and gave Buterin the start-up money he needed to drop out of school and pursue its development. When this money ran dry, Buterin needed an additional source of financing. He decided to issue digital assets on his blockchain known as ether (ETH), and sell them to the public in a crowdsale so owners of this asset would be able to participate and have access to this new financial system. In just over a month, Buterin raised $18.4M USD and set the stage for a new way of financing known as an Initial Coin Offering (ICO). Other companies soon followed suit and ICOs became a cost effective and fast way for companies to raise capital. In the past twelve months alone companies have raised more than $10 billion from these public crowdsales, as of the writing of this article.

Issues with ICOs

However, ICOs do come with their own set of risks. It was clear from investor behavior that many were investing in these new assets expecting to see a return meeting the definition of a security outlined by the Howey Test. Essentially the Howey Test is a four-part litmus test used by the U.S. Securities and Exchange Commission (SEC) to determine if assets meet the standards of an investment contract. This test states that if money was invested, and it was invested into an enterprise, and the investment came with a reasonable expectation of profits from the investor, and lastly that this realization of value was due to successful operation of the business, then the standards have been met to determine that this asset is a financial security.

Failure to comply with U.S. federal securities laws can yield punishment from the SEC as we have recently seen in the case of Paragon and Airfox, which were two companies who conducted an ICO in 2017 and misrepresented their tokens as a utility and not a security as defined by the Howey Test. Neither Airfox nor Paragon registered their ICOs pursuant to the federal securities laws, nor did they qualify for an exemption to the registration requirements. The SEC found both companies in violation of securities laws and has forced them to register their tokens as securities pursuant to the Securities Exchange Act of 1934 and file periodic reports with the Commission for at least one year (Palley, 2018).

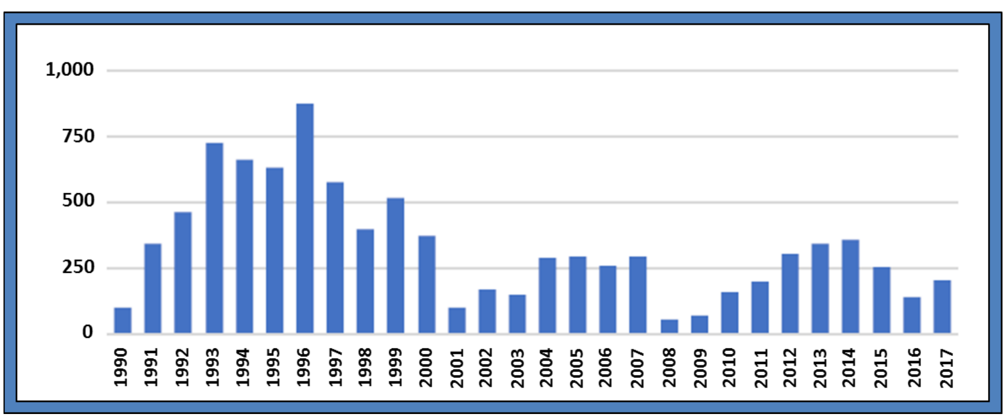
Tokenized Securities

As the SEC begins to adjudicate on ICOs, companies are taking notice and have begun issuing tokens that comply with securities laws and exemption requirements. These token generation events have been called Security Tokens Offerings or Digital Securities Offerings. As the name implies, these tokens, powered by blockchain technology are coming to market with compliance built into their issuance. These tokens are powered by a handful of new protocols and issuance platforms. These include the Polymath Protocol, Hyperion, Securrency, Swarm, and Harbor to name a few. Many platforms are still being developed and are looking to launch in the near term. Most platforms do not restrict themselves to only private share issuance; they are also aiming to tokenize real estate, debt, and importantly for this publication, commodities, among other assets. In our view, tokenized securities are transformative for a number of reasons.

The Need for Alternative Fundraising Strategies

Capital is the lifeblood of any business. It is essential in order to grow, finance an acquisition, pay employee salaries, develop product, and fund operations. Despite this obvious need, capital is becoming increasingly harder to find. The number of initial public offerings (IPOs), one of the most common ways to raise money in capital markets, has fallen by over 70 percent since its peak during the dot-com bubble, as shown below in Figure 1. Due to the development of legislation like the Sarbanes-Oxley Act in 2002, the process of undertaking a public offering and doing it compliantly has become incredibly lengthy, resource intensive, and expensive. The IPO process for a typical company lasts anywhere between six to nine months if all goes according to plan. Firms must also pay underwriter fees as well as significant legal expenses.

Figure 1
Number of IPO's, USA, 1990 - 2017

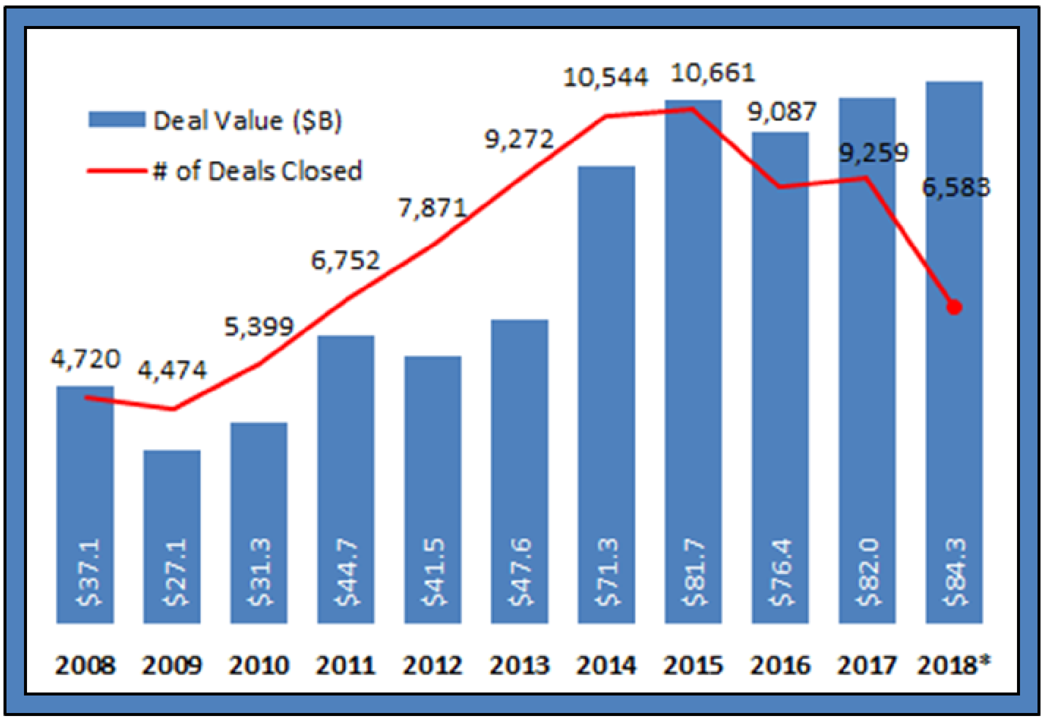


Source: Lux and Pead (2018).

Voter control has been a contentious issue that has caused some firms to rethink going public. In 2017, Snap Inc.'s IPO drew criticism for not giving shareholders any voting rights. The London Stock Exchange went so far as to refuse to list them for this reason. However, keeping voting power is a sentiment shared by a growing number of tech start-ups. Companies do not wish to see their vision for their product undermined by a desire to achieve profits in the short term.

The situation with private capital is also affecting public markets. The industry at large has undergone a significant amount of consolidation. Larger funds with over $1 billion to invest are beginning to become increasingly pervasive and dominate the landscape (Aberman, 2017). The consequences of this concentration of capital mean that although ticket sizes may be larger, the number of deals actually being handed out to companies is also on the decline, as shown below in Figure 2.

Figure 2
U.S. Venture Capital Activity



Source: *PitchBook Venture Monitor 3Q2018*
* As of September 30, 2018

The result of these trends is that firms are increasingly looking for alternative ways of raising capital that are less restrictive, time efficient, and cost effective. Reverse Takeovers (RTO), the process of going public by purchasing a shell-company that is already listed on an exchange, are becoming more popular as it is seen as a quicker and more cost effective way to have shares publicly traded. In April 2018, Spotify went public through what is known as a direct listing. By doing so they did not end up procuring the services of an investment bank to underwrite the deal and did not sell any new shares. It is estimated that by going through this process they saved around $63 million (Pisani, 2018). This scenario, in addition to other strategies such as equity crowdfunding and the formation of Capital Pool Companies (CPC), demonstrates the desire on the market for alternative fundraising methods. Tokenized securities offerings can fill this void due to quicker and cheaper deal execution, programmable governance and voting rights, as well as access to global pools of capital.

Proactive Regulatory Compliance

Another large change that may come about with the inception of security tokens is a new ability for regulators to take a proactive approach to compliance. The law and technology experience have an interesting relationship. Common law is a legal standard practiced in Canada, the United States, the United Kingdom, and Australia among others. It is based on the principle of *stare decisis*, also known as legal precedent. Judgements in the courts are made based on the outcomes of past cases and applied to the situation at hand. In this way, the law evolves by looking to the past to inform the future. This evolution is also painstakingly slow, and decisions and outcomes can take weeks while new legislation can span months and years.

Juxtaposed to these cumbersome and backward-looking processes is technological innovation. Innovation only pushes in one direction: forward acceleration. Google's Chief Futurist and Director of Engineering, Ray Kurzweil, calls this the "Law of Accelerating Returns." This theory predicts the exponential growth of diverse forms of technological progress. Given this rapid technical acceleration in relation to how legal decisions progress, the law is frequently slow to develop frameworks that can adequately compensate for the speed of technological development.

In the digital asset industry this dichotomy is very prevalent. After the ICO boom in late 2017, the SEC raced to govern the use of innovative new cryptocurrencies and digital assets with an adequate regulatory framework and ended up with the application of securities laws that date back to the 1940s.

However, due to the customizable and programmable characteristics of tokenized securities, regulators can actually use these assets as vehicles to enforce regulation proactively in the issuance of the token itself. While normal standard legal contracts can be seen as agreements between a number of parties with certain agreed upon terms, their conditions can only be enforced externally by regulators, lawyers, courts, or in the event of the parties actually holding up to their end of the bargain. In comparison, the defining feature of a smart contract deployed by a blockchain is a guarantee of execution. Contracts do not need to be enforced by some third-party authority: their terms are coded into the contract itself. In that way, when certain conditions are met, they are autonomously executed. What this means for tokenized securities is that securities law and legal terms can essentially be programmed into the issuance of the token itself to ensure that throughout the asset's life, it is constantly abiding by the rules. Other features such as voting rights and dividend payments can experience these same benefits. These rules form the backbone of popular security token standards.

This progressive approach is in stark contrast to the backward-looking approach of the law but represents an opportunity for regulators, for once, to get out in front of innovation. We feel that this ability is of such magnitude that regulators may one day make it mandatory for any securities issuance.

Global Access and Networked Investor Pool

The power of financing companies using networked technologies was first demonstrated during the ICO boom. In early 2017, Brendan Eich, the former Chief Executive Officer of Mozilla Firefox, raised $35M in 30 seconds to finance Brave, his new blockchain-based Internet browser. Meanwhile, Bancor, a digital asset liquidity provider, raised $153 million in just under 3 hours. We are not aware of any investments of this magnitude being accomplished in such an efficient manner.

While the replacement of financial intermediaries with automated services plays a large role in this, other factors are also important in allowing for these speedy capital raises. The other factors include (a) the ability to be educated on a sound investment opportunity using information dissemination on the web, and (b) the ability to actually invest in the new venture itself using the blockchain. These features result in the inclusion of retail investors and a free-market exposure to large global pools of capital.

Larger global investor pools are also realized by enabling financial access and participation. One of the defining features of tokenized securities involves a concept known as fractional ownership, as also covered in Cohen and Quintero (2019). This is where investors can experience the right to purchase a certain percentage of an asset. Where this may have the greatest impact is in unlocking liquidity in instruments that would have been otherwise frozen or hard to trade, as well as in assets that are too expensive too solicit investment from most investors. The most commonly cited examples include gold, diamonds, and rare artwork, which are assets that are inherently expensive but also come with significant storage and security costs. Others include high-value real estate and even ownership in professional sports teams, assets that have typically only been available to the few. Tokenizing these assets invites financial inclusion and participation, democratizing access to high-value investment opportunities for those that at least meet accredited investor laws.

Issues

Nevertheless, compliant token issuers still face challenges in the nascent market as secondary market exchanges do not yet have the promised liquidity pool needed to truly capture the full value of security tokens. Currently, to be able to trade security tokens compliantly, exchanges must have an Alternative Trading System (ATS) license. There are only a handful of companies that have these licenses and even fewer that are live. Only Open Finance and Tzero are actively trading these tokens and volumes have been low at the start. If one were to offer a security token today, there would be no secondary market to trade on. In addition, token holders would most likely have to hold the token between six-to-twelve months given the type of exemption the security has been filed under.

As holding periods are lifted and exchanges go live, only then can the promise of security tokens be realized. We would argue that we are not far away: we estimate that by 2020, more than ten security token exchanges will be live with hundreds of tokens traded. Security tokens hold promise for a new wave of adoption in the blockchain space. We recommend that market participants stay abreast of these advancements over the next few years because of their potentially large impact on capital markets in general and commodity investing in particular.

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