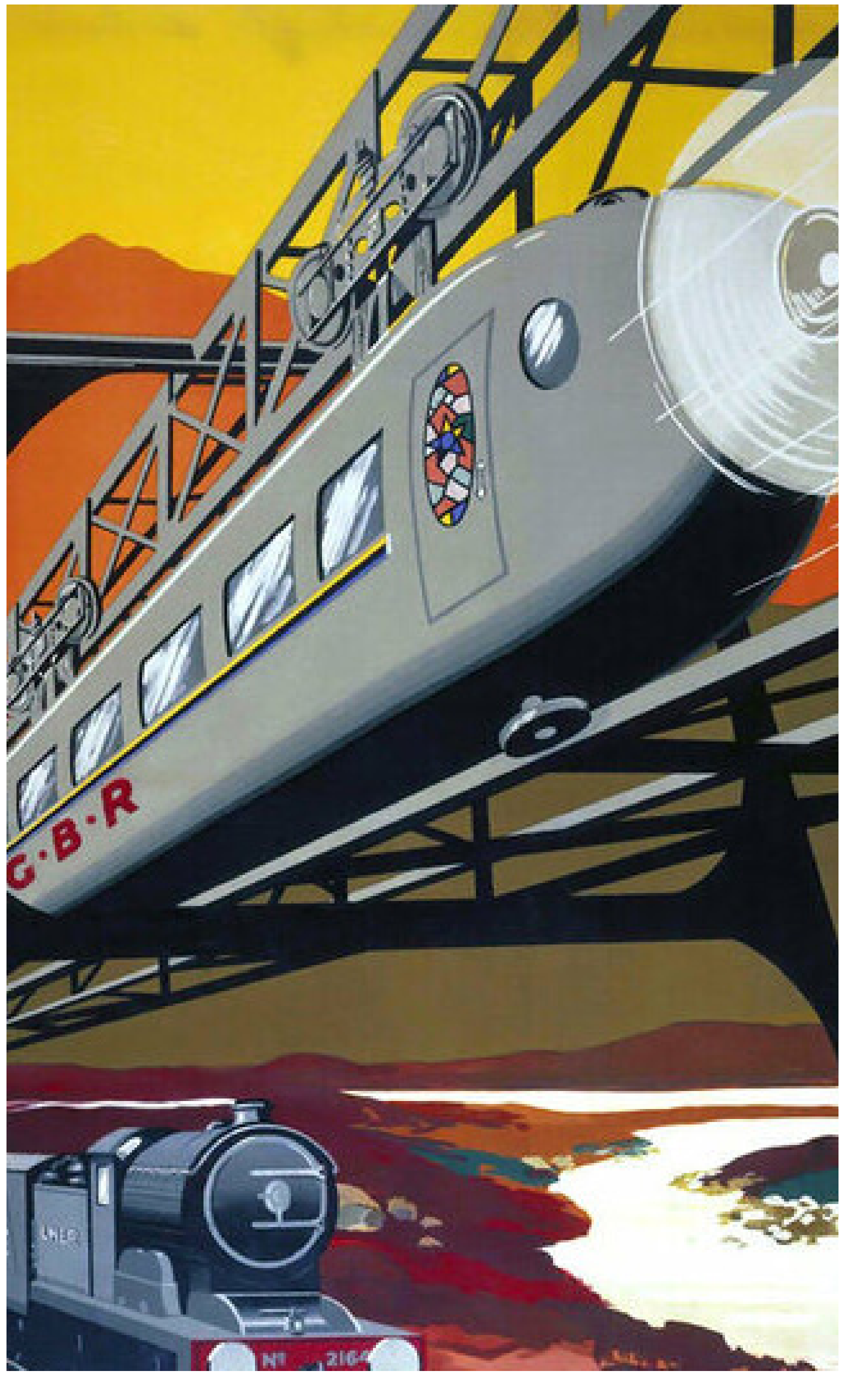
J.P. MORGAN CENTER FOR COMMODITIES
UNIVERSITY OF COLORADO DENVER BUSINESS SCHOOL

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

WINTER 2021



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GLOBAL COMMODITIES APPLIED RESEARCH DIGEST
Vol. 6, No. 2: Winter 2021
Index of Articles

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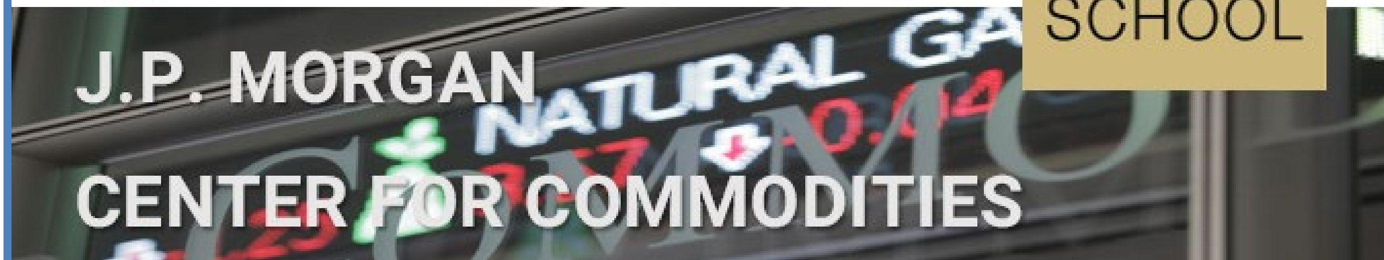

The JPMCC is positioned as a collaboration between business and academia across the broad agriculture, metals, and energy commodity sectors. Our focuses include Commodity Business Education, Applied Commodity Research, and Commodity-Related Public Forums & Discourse.

Specialization in Commodities

Our commodity classes cover the dynamics of the physical commodity markets, supply chains, data analytics & forecasting, risk management and trading.

4 Courses – 12 Credit Hours – Evening Courses

Professional Education Opportunities

We offer various professional education courses throughout the year. Our classes are currently:

Energy & Commodity Analytics for Analysts | Energy Analytics & Big Data for Managers

Masterclass in Commodity Trading & Hedging

Check out our website for more information on dates, prices, and new classes.

Commodity Research

In addition to the *GCARD*, the JPMCC sponsors an annual Commodities Research Symposium where global commodity thought leaders and prominent stakeholders from both academia and industry convene to discuss critical thinking and new research related to commodities.

Upcoming Webinars & Recorded Sessions

Follow us on LinkedIn and our Website for information.

Contact Erica Hyman for more information or to schedule a visit to the Business School.

Erica.Hyman@ucdenver.edu; 303-315-8019

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

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

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 in association with Premia Education, Inc.

The JPMCC's leadership team is as follows. Thomas Brady, Ph.D., is the JPMCC's Executive Director. The JPMCC's Research Director is Jian Yang, Ph.D., CFA, who is also the J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Discipline Director and Professor of Finance and Risk Management at the University of Colorado Denver Business School. The JPMCC's Program Manager, in turn, is Erica Hyman. Periodic updates on the JPMCC's activities can be found at https://www.linkedin.com/school/cu-denver-center-for-commodities/.

The JPMCC's scholars are as follows. Hilary Till is the JPMCC's Solich Scholar, and Robert Greer is the Center's Scholar in Residence. In addition, the Chairman of the JPMCC's Industry Advisory Council is Chris Calger, Managing Director, Global Commodities, J.P. Morgan.

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* was seeded by a generous grant from the CME Group Foundation and is published twice per year. The *GCARD* is currently supported by funding from Integrated Portfolio Intelligence LLC; FourPoint Energy; and the CME Group.

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/.

Since the Spring of 2016, the *GCARD*'s editorial staff have been as follows. The *GCARD's* Editor is Ms. Hilary Till, M.Sc. (Statistics) and Member of the JPMCC's Research Council. The *GCARD's* Editorial Assistant is Ms. Katherine Farren, CAIA.

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* also benefits from its academic and professional society partnerships in furthering the international recognition of the digest. These partners have included ECOMFIN, the IAQF, and CAIA. Specifically, the Director of the Energy and Commodity Finance Research Center (ECOMFIN) at the ESSEC Business School (France, Singapore) serves on the *GCARD*'s Editorial Advisory Board while the *GCARD*'s professional society partners include the International Association for Quantitative Finance (IAQF) and the Chartered Alternative Investment Analyst (CAIA) Association.

The Commodity Trading Association (CTA) is the latest professional society partner for the *GCARD*. This association comprises the professional graduates in commodity trading programs at the University of Geneva (Switzerland) and has distinguished itself over the past few years by organizing outstanding professional events that create unique networking opportunities for active professionals in the commodity trading, shipping, and financing industries.

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.

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J.P. Morgan Center for Commodities (JPMCC)

The JPMCC is positioned as a collaboration between business and academia across the broad agriculture, metals, and energy commodity sectors. Our mission includes commodity business education, applied commodity research, and commodity-related public forums & discourse.

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 in association with Premia Education, Inc. The JPMCC's leadership team is as follows. Thomas Brady, Ph.D., is the JPMCC's Executive Director. The JPMCC's Research Director is Jian Yang, Ph.D., CFA, who is also the J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Discipline Director and Professor of Finance and Risk Management at the University of Colorado Denver Business School. The JPMCC's Program Manager, in turn, is Erica Hyman.

Update from the Executive Director

This article provides a brief update from Dr. Thomas Brady on the many events and initiatives that have taken place this year, including (a) the addition of three new Industry Advisory Council members; (b) two new *GCARD* Editorial Advisory Board members; (c) the *GCARD* Best Article Award; (d) the Center's outreach and collaboration initiatives; (e) the upcoming Spring 2022 academic classes; (f) the "Leadership in Commodity Trading & Supply Networks" Global Executive Programme; (g) the Center's Professional Education offerings; and (h) a review of the August 2021 international commodities symposium.

Executive Director's Commentary

This article discusses why it is essential to prepare the next generation for lucrative employment opportunities across commodity sectors and notes the skills that students will need for a successful career in commodities.

Research Director Report

In this report, Dr. Jian Yang provides updates about recent JPMCC research activities from March 2021 until September 2021. In particular, Dr. Yang discusses (a) the most recent JPMCC international commodities symposium; (b) a study that advances research on commodity futures volatility spillovers; (c) the continuing media attention on the research director's crude oil and agricultural analyses; and (d) other commodity research publication updates.

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* periodically draws from insightful work 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.

Research Council Corner

The U.S. Department of Agriculture (USDA) produces monthly marketing-season-average price (SAP) forecasts for major U.S. crops that are closely watched by farmers and commodity market participants. For decades, the USDA published SAP forecast ranges whose upper and lower bounds had no statistical significance. In 2019, the USDA switched to publishing monthly single-point SAP forecasts. This paper argues that conducting and publishing density forecasts, or providing intervals based on those densities, would be very valuable to consumers of the SAP forecasts.

Research Council Corner
(Continued)

This article notes how one can gain considerable insights into market behavior by searching for asymmetry and irregularities in patterns in the price discovery process and uses the crude oil market as an example. The article is based on the author's keynote presentation at the JPMCC's August 2021 international commodities symposium.

Research Digest Article

This article studies whether the extreme price co-movement of commodity futures can be exploited to anticipate future industrial production (IP) growth. For this purpose, an empirical model is estimated to derive a measure that characterizes upside and downside price extremes. The derived price extremes are shown to be positively associated with IP growth over the next quarter. The findings further suggest the presence of an asymmetry: the association corresponding to downside extremes is robust whereas that of upside extremes is weaker. The findings reinforce the informational friction theory as well as those financial studies that emphasize downside risk in financial markets.

Editorial Advisory Board Analyses

The paper presents selected results from the comprehensive study of the volatility risk premium (VRP) in the oil market. We introduce the smile of VRP that represents variation in profitability and risk of this systematic strategy across option moneyness and maturities. We identify the structural break in VRP evolution over time driven by behavioral changes among producer hedgers and the securitization of the strategy by financial institutions.

In this article, the author describes how to compare the emissions from bitcoin and gold. The calculations are based on the relevant emissions from production, without delving into later lifecycle emissions. The goal is to give investors useful "rules of thumb" for understanding the orders of magnitude at play.

Industry Analyses

The general theory of storage suggests that the level of inventories is a key factor in determining the basis over time. The basis is the difference between the price of oil in the futures market and the price of oil in the spot market. As an indicator of future price movements, the basis follows a different dynamic when inventories are in scarce supply or in surplus, implying that there are different market states that reflect different underlying crude oil market conditions. We apply a Markov regime switching model to analyze this complex relationship, using a spread option value of storage metric to represent market structure, which enables us to draw preliminary conclusions on how to potentially impact oil-market-price stability via precise inventory decisions.

Early-2021 saw synchronous gains for commodity prices, prompting predictions of an imminent commodity super cycle. Price increases both resulted from, and contributed to, supply-chain bottlenecks and broader price inflation in the world economy. Looking ahead, while cyclical inflation drivers may ease, policy choices on economic regeneration, the energy transition, and the reshoring of manufacturing could raise supply-chain costs on a more structural basis over the longer term. The article is based on the author's presentation at the JPMCC's August 2021 international commodities symposium.

In the early days and months of the COVID-19 pandemic, the dairy industry faced challenges—such as shifts in supply and demand—as food service demand fell and retail demand skyrocketed. However, the industry ultimately emerged intact thanks to adjustments such as portfolio simplification and manufacturing flexibility. The authors explore what the experience was like for the dairy industry, and how executives plan to proceed. The authors recommend that the dairy industry expand the talent pool and ways of working, embrace a "One Health" approach, and establish flexible supply chains that can respond to unexpected disruptions.

Editorial Advisory Board News

This section provides professional updates on EAB members, as well as news on (a) their participation in conferences, (b) publication activity, (c) citations, and (d) public appearances.

Executive Programme: Leadership in Commodity Trade & Supply Networks

The "Leadership in Commodity Trade and Supply Networks" programme is unique in the world. It is the only programme that is designed for business executives, and which takes place across three continents. The programme will be offered by Erasmus University, in partnership with Singapore Management University and the J.P. Morgan Center for Commodities. It is interdisciplinary and focuses on developing leadership skills and strategic thinking. The next offering will begin in January 2022 with in-person sessions in Rotterdam. Participants will then participate in classes at the JPMCC in Denver (March) followed by a week in Singapore later in May.

Update from the Executive Director of the J.P. Morgan Center for Commodities

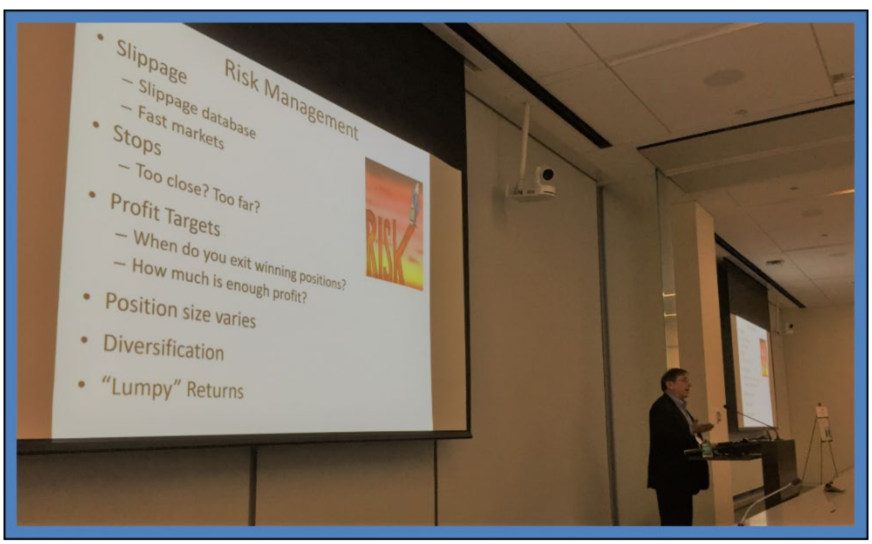
Welcome to the twelfth issue of the *GCARD*! And thank you also to the *GCARD*'s Industry Sponsors and the JPMCC's Research Council, Industry Advisory Council, & the *GCARD* Editorial Advisory Board for their continued support of this publication.

Industry Advisory Council

The J.P. Morgan Center for Commodities at the University of Colorado Denver Business School is delighted to welcome three new members of the JPMCC's prestigious Industry Advisory Council, who include (a) Fiona Boal, Global Head of Commodities and Real Assets at S&P Dow Jones Indices; (b) David Green, Director, Trading and Origination at Xcel Energy; and (c) Saad Rahim, Chief Economist, Trafigura. We look forward to learning from their expertise and working with them and the rest of our Advisory Council to broaden the reach and relevance of the JPMCC.

***GCARD* Editorial Advisory Board**

We are also happy to announce the appointment of two additional commodity investment experts to the *GCARD*'s Editorial Advisory Board: Mark Shore and Gillis Björk Danielsen. Mark Shore is the Clinical Professor of Finance at DePaul University in Chicago. He is also the Chief Research Officer of Shore Capital Research (@shorecap on Twitter). He recently provided research assistance for the July 2021 *GCARD* Newsletter article, "Commodities, Crude Oil, and Diversified Portfolios."



Mark Shore, Clinical Professor in Finance at DePaul University, presenting on "Risk Management of a Commodity Trading Advisor: Behind the Curtain" at William Blair in Chicago.

Gillis Björk Danielsen is a Senior Portfolio Manager at APG Asset Management. APG is a large pension fiduciary in The Netherlands, investing responsibly across all asset classes. At APG, he works in the commodities investment team, focusing on the quantitative and ESG aspects of the investment process. In addition to contributing to the current issue of the *GCARD*, Björk Danielsen's previous *GCARD* article covered whether a responsible investor should invest in commodity futures.

Welcome, Mark and Gillis, to the *GCARD*'s team!

***GCARD* Best Article Award**

Dr. John Fan's co-authored article on "The 'Necessary Evil' in Chinese Commodities Markets**"** was selected for this year's *GCARD* Best Article Award.

Dr. Fan's research digest article summarizes his co-authored paper with Dr. Di Mo of RMIT University (Australia) and Tingxi Zhang of Griffith Business School (Australia) that was published this year in the *Journal of Commodity Markets*. Dr. Fan is a Senior Lecturer in Finance at Griffith Business School (Australia) and is also a member of the *GCARD*'s Editorial Advisory Board**.** Congratulations to Dr. Fan!

Center Outreach and Collaboration

"Talking Commodities" Podcasts

Over the past few months, Dr. Tom Brady, Executive Director of the J.P. Morgan Center for Commodities, has worked extensively to increase the Center's recognition through webinars, partnerships, and outreach. The Center completed a second series of a commodities-focused podcast with London-based commodity artificial intelligence startup, ChAI. The podcast, "Talking Commodities," included interviews with several of our Industry Advisory Council members as well as commodity experts from around the globe. We want to thank the following three JPMCC Industry Advisory Council members for participating in these podcasts: Robert Greer, Senior Advisor, CoreCommodity Management, LLC and Scholar-in-Residence, JPMCC; Fred Seamon, Executive Director in Agricultural Markets, CME Group; and Sharon (Hyman) Weintraub, Senior Vice President, Gas and Power Trading – International, BP. One can view full episodes of these insightful podcasts at https://chaipredict.com/podcast-time-for-chai.

Applied Research Project

In addition, the Center has initiated a joint commodity applied research project concerning the development of a "Global Commodity ESG Index," in collaboration with a financial partner. We have hired a graduate research assistant who is assisting with this project.

Virtual Panels

In November, the JPMCC co-organized virtual panels on the following two topics: emerging technology in global commodities and also on winter energy prices.

Excerpt from the flyer for the "Emerging Technology in Global Commodities" virtual panel that took place on November 18, 2021.

Establishing commodity-related public education has been a key goal of the JPMCC's Executive Director, as discussed here.

The "Emerging Technology in Global Commodities" panel was co-organized with CU Denver's Institute for International Business and the Center for International Business Education and Research (CIBER). The panel covered blockchain applications across supply chains, new trading platforms, and risk management solutions. The featured panelists were James Sullivan, Head of Commercial Development, Stable USA; Ricardo Bebiano, Marketing, Technology Metal Markets; and Julie Tracy Lockwood, Global Business Services Consulting, IBM.

A virtual panel on "Winter is Coming … and Energy Prices are Spiking [in the U.S.]" was also co-organized with CU Denver's Global Energy Management (GEM) program. The featured panelists were Shikha Chaturvedi, Executive Director, Head of Global Natural Gas and Natural Gas Liquids Strategy, J.P. Morgan and Autumn Hong, Solution Associate Partner in Energy Insights, McKinsey & Company. The moderator was Dr. Michael Orlando, Managing Director, Econ One Research. Chaturvedi had previously contributed an article to the *GCARD* on the term structure of the natural gas futures market.

In December both the GEM program and JPMCC will be hosting a virtual panel on energy prices in Europe. The featured panelists are Fiona Boal, Global Head of Commodities and Real Assets at S&P Dow Jones Indices; Sharon (Hyman) Weintraub, Senior Vice President, Gas and Power Trading – International, BP; and Bernadette Johnson, Senior Vice President, Power & Renewables, Enverus. Boal and Weintraub are both members of the JPMCC's Industry Advisory Council while Johnson is the current Executive-in-Residence for both the GEM program and JPMCC. The webcast will take place on December 8, 2021 at 9:00 a.m. MT with additional information here.

Academic Classes

For the Spring 2022 semester, the JPMCC will offer 3 for-credit graduate level courses in 16-week online formats at the University of Colorado Denver Business School, which start in January 2022. These courses will prepare students to navigate commodity markets and broaden their financial acumen for successful careers in the finance, risk management, and commodity sectors and include (1) Commodity Trading, (2) Commodity Data Analysis, and (3) Commodity Valuation and Hedging. The application deadline is December 15, 2021. One can learn more here; and register here.

The instructors for these classes are respectively: (1) Joel Rubano, Founder of Instradev, LLC; (2) Dr. Daniel Jerrett, Chief Investment Officer of Stategy Capital LP and JPMCC Industry Advisory Council member; and (3) Dominick Paoloni, CIMA, Managing Principal and Chief Investment Officer at IPS Strategic Capital. Dr. Jerrett is interviewed in this issue of the *GCARD*, and he contributed a past article to the *GCARD* on commodity super cycles.

Global Executive Programme: Leadership in Commodity Trade & Supply Networks

The "Leadership in Commodity Trade and Supply Networks" programme is unique in the world. It is the only programme that is designed for business executives, and which takes place across three continents. The programme will be offered by Erasmus University, in partnership with Singapore Management University and the J.P. Morgan Center for Commodities. It is interdisciplinary and focuses on developing leadership skills and strategic thinking. The programme is both theoretically informed and hands-on with real world cases so as to provide a true learning experience across three continents. After a delay due to COVID-19 in 2020, we will be launching this programme in January 2022. Full details are included in the executive programme's brochure and on the programme's website.

Professional Education Courses

Jointly with CU Denver's GEM program, the JPMCC will be hosting the following two professional education classes during the Spring of 2022.

Masterclass in Commodity Trading & Hedging: This four-week online certificate course is for new hires on the trading desk, risk managers, analysts, and senior management. The course offers a complete perspective on institutional commodity trading. Participants will learn how professional traders distill information into an actionable perspective on the future of price, then select the optimal strategy to express that view of the market. The course's instructor is Joel Rubano, Founder of Instradev, LLC.

Energy and Commodity Analytics for Analysts: This four-week online course for analysts and technical professionals will take a deep dive into energy and commodities analytics. Designed for those who want to learn best practices on commodity data analytics, visualization, and forecasting, the course offers hands-on projects and real-world data. Participants will learn commodity data analysis utilizing EViews, an industry-leading data management and analysis software package. The course's instructor is Dr. Daniel Jerrett, Chief Investment Officer of Stategy Capital LP and JPMCC Industry Advisory Council member.

Updates on the professional education courses will be available here.

Research Symposium

As noted in the Research Director's Report, the Center hosted its 4th annual research symposium virtually from August 16 through August 18, 2021. With over 500 registrations from 36 countries, this was our largest symposium to date. We plan to return to a fully in-person and/or hybrid format for the symposium in 2022 and are looking forward to connecting with colleagues old and new next year.

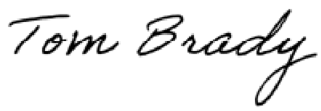
Dr. Thomas Brady, Ph.D., presenting at a JPMCC international commodities symposium. Dr. Brady is the JPMCC's Executive Director at the University of Colorado Denver Business School and is also a Managing Director at Capitalight Research in Canada.

Executive Director's Concluding Note

I welcome *GCARD* readers staying up-to-date on the JPMCC's numerous activities by visiting the [Center's website] or by following the Center and *GCARD* on our two LinkedIn sites, https://www.linkedin.com/school/cu-denver-center-for-commodities/ and https://www.linkedin.com/company/jpmcc-gcard.

We hope you enjoy reading this latest issue and always feel free to contact me for further information and questions.

Best Regards,



Tom Brady, Ph.D.
Executive Director, J.P. Morgan Center for Commodities

The Importance of Commodity Education

Thomas Brady, Ph.D.
Executive Director, J.P. Morgan Center for Commodities, University of Colorado Denver Business School; and Managing Director and Editor, *Commodities Report*, Capitalight Research, Canada

This article discusses why it is essential to prepare the next generation for lucrative employment opportunities across commodity sectors and notes the skills that students will need for a successful career in commodities.

Thomas Brady, Ph.D., Executive Director of the J.P. Morgan Center for Commodities (JPMCC), presenting at a JPMCC international commodities symposium at the University of Colorado Denver Business School.

Introduction

During my career, which has included positions in both the mining and energy commodity sectors, I have had the opportunity to meet well-seasoned industry professionals. Through many conversations, I have always been intrigued with how people initially become attracted to commodities to the degree where many of us eventually dedicate entire careers to the sector. Some may have had a parent or relative that provided insight or nudged them in certain directions. However, the vast majority (including myself), have paths that echo the themes, "… growing up and while in college, I never heard or thought of commodities …" and "… I fell into my first job and it ended up being a great career filled with huge challenges, the ability to work with others from different cultures, and the opportunity to travel the world."

As many of us remember, entry level positions had a sink-or-swim approach, requiring dedicated hours and sacrifice to learn the relevant commodity markets and necessary skills to get up to speed and demonstrate value quickly. Those more fortunate may have had the benefit of solid mentorship from more experienced colleagues that helped them on their paths. While some companies have proven better than others at mentorship and internal training, for most people, these activities are unstructured with the overwhelming focus on new employees to prove their worth.

For those seeking more formal, university-based commodity education, opportunities are sporadic. Opportunities may only offer targeted commodity-specific programs including agricultural economics, energy management, and transportation economics. In general, very few universities offer programs that cover multiple commodity sectors. (The Geneva School of Economics and Management offers a Master's degree in commodity trading, addressing shipping and trading across the energy and metals sectors. Erasmus University in Rotterdam, and Bayes Business School and Imperial College, both in London, also provide a more-broad commodity focus.)

For those seeking more informal or individual training in commodities, the results that come up when searching "commodity education" or "commodity training" on the internet are interesting. The results are overwhelmingly centered on commodity trading. What is lacking are comprehensive resources providing understanding of the many non-trading aspects, including how commodities are produced, the implications of financing, the associated logistics of how commodities are transported and flow through supply chain networks, the processing and refining required, the mechanics of commodity trading and risk management from both physical and financial levels.

In short, without proper mentorship and/or on-the-job training, there are limitations to obtain broad-based education and upfront knowledge in commodities. From my personal industry experience, predominately in the strategy and finance organizations of global producing and consulting companies, I note three overall attributes that enabled both myself and my employees to enter and succeed in their commodity careers, which I believe hold true across all commodities.

The first includes solid skills in obtaining data. The individual must be knowledgeable of and versed in obtaining necessary data from sources such as Bloomberg, Thomson Reuters, FactSet, and others. Secondly, the individual should possess the basic quantitative skills to analyze the previously obtained information and data. These may include financial modeling, basic statistics, econometrics, and risk management. Solid programming skills to handle large and cumbersome datasets (such as R and/or Python) are also important. Last, and most importantly, the individual must have the ability to take information and analysis obtained from the prior steps to make sound and succinct recommendations to senior managers, CEOs, and boards of directors. This requires a broad understanding of market, industry, and geopolitical trends to evaluate both the upside and downside risks. This third attribute becomes more important when moving up the corporate ladder.

At the JPMCC, we focus on these career-building skills through undergraduate, graduate, and professional commodity education classes. Also included in our mission is the generation of practical, applied commodity research targeted for industry use. The JPMCC has recently entered a partnership with Erasmus University's leadership program, which also includes Singapore Management University. In this program, candidates with high potential from industry will travel to three continents and focus on leadership challenges in commodity trade and supply networks and engage in reflexive learning. The JPMCC constantly works to improve our courses and opportunities to reach our vision of being the global nexus for commodity talent, experts, and industry.

Endnote

This article originally appeared in the "Leadership Thoughts" section of *Human Capital (HC) Insider*, https://hcinsider.global.

Author Biography

THOMAS BRADY, Ph.D.
Executive Director, J.P. Morgan Center for Commodities, University of Colorado Denver Business School; and Managing Director and Editor, *Commodities Report*, Capitalight Research, Canada

Dr. Thomas Brady is a mineral and commodity sector economist and is currently the Executive Director of the J.P. Morgan Center for Commodities at the University of Colorado Denver Business School and founder of Brady Commodity Advisors, LLC. He also the Managing Director and Editor of Capitalight Research's *Commodities Report* in Canada. Most recently Dr. Brady was the Chief Economist at Newmont Mining Corporation responsible for generating key commodity price, foreign exchange and other financial assumptions used throughout the company. Previously at Newmont, he led the Strategic Planning function that developed and implemented portfolio modeling analytics and also held positions in Investor Relations, Treasury and Corporate Development.

Prior to rejoining Newmont, Dr. Brady was a Senior Manager at Risk Capital Management, a consultancy that advised energy and natural resource companies on financial risk, valuation and commodity hedging.

Dr. Brady holds a Ph.D. in Mineral Economics with research emphases in commodity markets from the Colorado School of Mines. In addition, he holds a Master's degree in Mathematics, also from the Colorado School of Mines.

Dr. Brady had last contributed an article to the *GCARD* with "A Review of Global Silver Supply Trends."

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

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

Dr. Jian Yang, Ph.D., CFA, J.P. Morgan Endowed Chair and JPMCC Research Director, welcoming participants at a JPMCC international commodities symposium.

In this brief report, the J.P. Morgan Center for Commodities' (JPMCC's) Research Director will provide updates about recent JPMCC research activities from March 2021 through September 2021. This report discusses (a) the most recent JPMCC international commodities symposium; (b) a study that advances research on commodity futures volatility spillovers; (c) the continuing media attention on the research director's crude oil and agricultural analyses; and (d) other commodity research publication updates.

The 4th Annual JPMCC International Commodities Symposium

The JPMCC organized the 4th annual international symposium as a virtual conference, which took place from August 16 through August 18, 2021. The 4th annual symposium was originally scheduled for 2020 but was cancelled due to COVID-19, so the last symposium had been in 2019.

As in the past, the 2021 symposium continued its core strength of providing a common forum for academics, policy researchers and practitioners who have expertise in the commodity markets. The symposium included four academic sessions and two industry panels, presenting academic and applied research from (a) top universities (*e.g.*, Yale; Oxford; Columbia; University of California, Berkeley; and the University of Pennsylvania), (b) top policy institutions (*e.g.*, the Federal Reserve System, International Monetary Fund, and World Bank), and (c) major companies (*e.g.*, J.P. Morgan, Uniper, and Trafigura). The two keynote speakers were Charles Calomiris, Ph.D., the Henry Kaufman Professor of Financial Institutions at Columbia Business School and the former Chief Economist at the Office of the Comptroller of the Currency, and Bluford Putnam, Ph.D., the Chief Economist of the CME Group. Dr. Putnam also serves on the JPMCC's Research Council and generously contributed an article to this edition of the *GCARD* on his keynote speech regarding new methods for analyzing the crude oil markets.

The symposium's industry panels covered (a) ESG and the Applicability to Commodities, which was moderated by Bloomberg's Kartik Ghia, Ph.D., and (b) whether we are in a "Commodity Super Cycle", which, in turn, was moderated by the CME Group's Owain Johnson. Dr. Ghia is a member of both the JPMCC's Industry Advisory Council and the *GCARD*'s Editorial Advisory Board; and he also contributed a recent co-authored article to the *GCARD* on the applicability of Environmental, Social, and Governance considerations to commodity index construction. In addition, another *GCARD* author, David Fyfe, participated in the symposium's commodity super-cycle panel. Fyfe is the Group Chief Economist for Argus Media; and his *GCARD* article is available here.

Notably, the symposium was featured in some international media publications (*e.g.*, the *China Futures* magazine of the China Futures Association and *Futures Daily*). The symposium will also be the subject of a special issue from a core finance academic journal, *Journal of Futures Markets*, to be published in May 2022.

In addition, the commodity symposium's rich blend of academic and practitioner presentations are available here. Many of the symposium's presenters, discussants, and facilitators have contributed to past issues of the *GCARD*, as covered here, so we are grateful that so many leading academic and industry commodity experts continue to be involved in the JPMCC's dissemination of original insights into the commodity markets.

Despite challenges, the symposium achieved greater success than past conferences in some respects. It received **the largest number of submissions**, coming from researchers from eleven countries (Canada, China, Czech, France, Germany, India, Italy, Japan, Switzerland, the U.K., and the U.S., in an alphabetical order). It was also **more inclusive and more representative internationally than previously**. This was the first time that the symposium received submissions and participation in the conference program from Japan and India, two major Asian countries ranking No. 3 and No. 7 in the world (in terms of 2020 Gross Domestic Product). The symposium program had a poster session including additional papers from Ph.D. students. The symposium also had the largest audience thus far at our annual symposium with over 500 online registrants**. The participants from 23 countries** were also more diverse than at previous symposia.

The 4th annual international commodities symposium was co-organized by the JPMCC's Research Director and by Tom Brady, Ph.D., the JPMCC's Executive Director. Erica Hyman, the JPMCC's program manager, served as the coordinator for the symposium.

A Study Advancing Research on Commodity Futures Volatility Connectedness

The article, "Volatility Spillovers in Commodity Futures Markets: A Network Approach," coauthored by the research director was published online by the *Journal of Futures Markets* in late September 2021. It advances research on commodity futures connectedness with interesting implications on multiple fronts. First, this is the first study to comprehensively explore commodity volatility spillovers across 25 global commodity futures markets from the perspective of low frequency/long-term (from a month up to a year) versus high frequency/short-term (within a week). The total commodity futures volatility connectedness, using the paper's model, averages 42%, and ranges between 31% and 63% during 2006 to 2019. Thus, commodities should be treated as a broad asset class from the volatility spillover perspective, and commodity specialists in a particular commodity should also watch for volatility or market situations in other commodity markets.

Second, the same set of commodities play the most active role in both receiving and sending volatility shocks. They also behave similarly in both short-term versus long-term volatility spillovers. In particular, crude oil and soybeans as individual commodities, and energy and grains as groups, stand out in driving the commodity volatility connectedness. The category of agricultural commodities is also heterogeneous, with livestock and softs as the most isolated in the commodity volatility connectedness network. Market participants should pay particular attention to other commodities in the same group in the short term, but also to other commodities in other groups in the long term.

Third, while the magnitude of commodity volatility connectedness is largely (on average about 60%) determined by short-term volatility spillovers, the fluctuation of commodity volatility connectedness arises mostly from commodity volatility spillovers in the long term, which is significantly driven by broad economic conditions in the U.S. This implies that the financialization of commodities might have limited effects on explaining the fluctuation of commodity price volatility and spillovers, particularly in the long term.

Continuing Media Attention on the JPMCC Research Director's Crude Oil and Agricultural Analyses

The JPMCC Research Director's analyses of China's oil futures contracts have already received much international media attention; this continued around the 3rd anniversary of the launch of China's oil futures in late March 2021. The analysis of, and suggestions for, China's oil futures markets were based on multiple research projects, which were earlier published as a cover story in the October 2020 issue of the *China Futures* magazine. The research director's insights were also extensively quoted by the only national English newspaper in China, *China Daily*. The same piece with some modifications was also republished by *The Star*, the most popular English newspaper in Malaysia. In addition, the research director published his second op-ed in English in *Beijing Review* (China's only national news magazine in English) in early April 2021, where the research director was introduced by the magazine as "an internationally recognized scholar on derivatives securities and markets." In this article titled, "Secrets of China's Crude Oil Futures," the research director again shared a number of new findings on China's oil futures market.

The research on China's oil futures by the research director was even more extensively featured by the media in Chinese. These media outlets include *Economic Daily* (of the State Council of China), *China Review News Agency* in Hong Kong, *China Petroleum Daily* of China National Petroleum Corporation (the fourth largest company in the world in 2020), among others. The research director's insights were also featured by more news articles in Chinese (such as *China Petroleum Daily*) when the Shanghai International Energy Exchange celebrated the one-month anniversary of China's crude oil options in late July 2021.

In addition, in mid-March 2021, *Financial News* (of the People's Bank of China) published an exclusive interview with the research director where he shared his analysis into the price discovery performance of China's agricultural futures markets, based on his journal article published in April 2021. The news item was also reposted by Zhengzhou Commodity Exchange in China.

Other Commodity Research Updates

The July 2021 issue of the *Journal of Futures Markets* (*JFM*) included a retrospective evaluation of the *JFM*'s articles during its first 40 years of publication. This evaluation noted that a 2001 *JFM* article on U.S. commodity futures markets, which was co-authored by the JPMCC's Research Director, is ranked **among the top 20 most cited articles** out of about 2,000 journal articles during the period. The research director was the article's lead author, and the article is based on his dissertation.

The research director's co-authored article titled, "Price Discovery in Chinese Agricultural Futures Markets: A Comprehensive Look," published in April 2021, was recently included in the August 2021 issue of the World Banking Abstract (WBA) published by Wiley. According to its editorial statement, WBA is published every two months, and in each issue includes 250 concise abstracts of "key, contemporary articles of practical interest to banking and financial services managers" from 250 journals and other non-scholarly or non-English periodicals.

Conclusion

While the situation is apparently getting better, COVID-19 continues to have impact on all of us. We hope we would meet in person at the 2022 symposium, if not earlier. We wish everyone a healthy and safe winter!

Best Regards,

Jian Yang, Ph.D., CFA
Research Director, J.P. Morgan Center for Commodities

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Incorporating Uncertainty into USDA Commodity Price Forecasts: A Review

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The U.S. Department of Agriculture (USDA) produces monthly marketing-season-average price (SAP) forecasts for major U.S. crops that are closely watched by farmers and commodity market participants. For decades, the USDA published SAP forecast ranges whose upper and lower bounds had no statistical significance. In 2019, the USDA switched to publishing monthly single-point SAP forecasts. This paper argues that conducting and publishing density forecasts, or providing intervals based on those densities, would be very valuable to consumers of the SAP forecasts. In a recent paper published in the American Journal of Agricultural Economics (2020), we use corn and soybean market data to demonstrate how a density forecasting format can improve the usefulness of USDA forecasts by simulating the historical performance of out-of-sample forecasts via different methods (in this review article, we cover the corn market alone). We use forward-looking, backward-looking, and composite approaches, and evaluate them based on commonly-accepted criteria. Backward-looking methods require little data yet provide significant improvements. For commodities with active derivatives markets, option-implied volatilities (IVs) can be used to generate forward-looking and composite models that reflect (and adjust dynamically to) market sentiment about uncertainty—a feature that is not possible using backward-looking data alone.

Each month, the USDA predicts the average price that farmers of major U.S. crops can expect to receive over the course of the commodity marketing year, referred to as the season-average price (SAP). These forecasts appear in the Department's monthly World Agricultural Supply and Demand Estimates (WASDE) report, and are closely watched by producers and government agencies, since their range affects expected farm payments and outlays (see, *e.g.*, Zulauf and Schnitkey, 2014).

For corn, the largest U.S. crop in terms of the number of bushels produced each year, USDA analysts make price predictions about the twelve-month marketing year (that covers September-August) over an 18-month forecasting cycle, beginning in May preceding the harvest, and continuing until October in the following calendar year. The final farmer-price-received value is published that following November. From April 1977 through April 2019, USDA published the SAP as an interval, with upper and lower price bounds that tended to tighten over the course of the forecasting cycle; late-cycle forecasts were regularly made as a point estimate. These forecasted bounds, however, were essentially meaningless: the USDA attached no statistical confidence to them—the probability that the price realized by farmers would lie within the extremes was not provided. As a result, the ranges were difficult to interpret for report consumers and market observers. To wit, Isengildina *et al.* (2004) showed that USDA intervals for corn and soybean prices had very low "hit rates", i.e., a low proportion of forecasts for which the realized prices fell within the projected bounds.

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The process that the USDA used to generate its SAP intervals was not public. According to Vogel and Bange (1999), it was "a complex one involving the interaction of expert judgment, commodity models, and in-depth research by Department analysts on key domestic and international issues." One might assume that published intervals were informed by historical data, such as realized volatility and past patterns of uncertainty resolution. However, given that the USDA published similar ranges at both volatile and tranquil times (Isengildina-Massa *et al.*, 2011), SAP forecasts that appeared in WASDE clearly did not accurately reflect market uncertainty about crop conditions.[1]

In 2019, the USDA chose to eliminate these SAP ranges altogether, in favor of publishing single price point forecasts in each month's WASDE for both commodities and livestock (USDA, 2019). The probability that a point forecast will be realized, however, is very low (and we explore that fact in detail below).

We argue that conducting and publishing density forecasts, or providing intervals based on those densities, would be very valuable to consumers of USDA forecasts, including government agencies attempting to plan program payments as well as other stakeholders who must make decisions about storage, marketing, and merchandising. In this article, we explain how probabilistic SAP densities can be constructed using backward- and/or forward-looking information, demonstrate how useful price intervals can be generated based on these densities, and document that these density methods outperform USDA's SAP forecasting approaches.

Each density method we consider has advantages. Because they require only the set of historical forecast errors, backward-looking densities can be generated for any commodity; their data requirements are low and they are easy to estimate. For commodities with liquid derivatives markets, we show that forward-looking information extracted from commodity option prices can improve forecast performance according to commonly-applied forecast evaluation criteria; intervals based on those densities would adjust to market sentiment, an important consideration in the current environment of policy uncertainty and trade tensions. Finally, we find that composite methods that blend backward- and forward-looking information can enhance SAP model performance. Since financial markets are efficient, this last result might seem surprising at first pass. Yet it reflects the intuition that prices for agricultural options on futures contracts reveal uncertainty about cash market prices in a single location at a single delivery date, whereas SAP are average commodity prices across the United States at the farm level, over the entirety of the marketing year: these differences explain why backward-looking data about average U.S. prices, as well as forward-looking data from the central options market, are both informationally useful.

Probabilistic Forecasting

Increasingly, private and public organizations involved in economic and price forecasting offer their predictions probabilistically. By indicating the forecaster's confidence level over a range of potential outcomes, probabilistic forecasts supply a much richer prediction profile to their consumers—as compared to a simple point estimate, whose chances of being realized are often very low.

Density forecasts of a given variable can be estimated using a few general approaches. Forward-looking methods are based on expectations about the future. Backward-looking methods are based on historical observations, or past forecast performance. Composite methods combine elements of both forward- and backward-looking techniques. Within each broad class, many different choices are available to the forecaster: the appropriate set of expectations from which to draw, the right timeframe of past observations to consider, whether or not to include exogenous variables, assumptions about the distributions followed by each of the variables that underpin the forecasting exercise, and so on.

Tay and Wallis (2000) trace the origin of density forecasts of macroeconomic variables back to the *Survey of Professional Forecasters*, developed by a partnership between the American Statistical Association and the National Bureau of Economic Research in the late 1960s, and later run by the Federal Reserve Bank of Philadelphia. By the 1990s, central banks around the world began to adopt the technique and to publish density forecasts of key macroeconomic aggregates in the form of "fan charts," whose widening color shades—resembling a handheld folding fan—indicate visually the level of certainty that forecasters place in each band of potential observations.[2]

On the one hand, researchers and governments have started using density forecasts to project price levels for some commodities, as well. For example, Trujillo-Barrera, Garcia, and Mallory (2016) adapt the methods of Taylor (2005), Liu *et al*. (2007), and Høg and Tsiaras (2011) to generate price density forecasts for lean hogs futures prices. For several energy commodities, the U.S. Energy information Administration adds confidence bands—built via forward-looking techniques—to the price forecasts offered in its monthly *Short-Term Energy Outlook* report. Internally, in the same vein, the USDA's Risk Management Agency (RMA) uses option-implied volatilities to develop premium rates for crop revenue insurance

(Goodwin *et al*., 2014), relying on their predictive power to provide information about the expected future distribution of market prices at a single time of year. On the other hand, USDA monthly SAP forecasts have, for decades, been published without any probabilistic context.

Enhancing USDA Price Forecasts

In this section, we describe various probabilistic techniques that can be used to enhance USDA price forecasts. For more information about how we implemented these methods and what data we used, please see the original article—Adjemian *et al.* (2020).

Backward-Looking Approach

One way to gauge uncertainty about a given forecast is to measure the historical reliability of previous forecasts made using the same model. By assuming that new forecasts will maintain the same level of reliability as past projections at the same step in the series (i.e., by assuming that the distribution of future forecast errors will follow the distribution of errors observed up to that point), the analyst can generate a probability density to quantify predictive uncertainty. This is precisely the type of approach used for grains and oilseeds by Isengildina-Massa *et al.* (2010) and Isengildina-Massa *et al*. (2011): at each forecast step, historical errors are used to construct "empirical confidence intervals" around projected commodity prices based on the method introduced by Williams and Goodman (1971).

A straightforward backward-looking method is to organize a histogram of the frequencies of various historical miss rates and apply it to the current forecast. Yet a richer probability density function can be estimated by fitting a function, such as a kernel, that smoothes the observations in the histogram. Compared to a histogram, an error-based density provides more flexibility to the SAP forecast, supplying a positive probability to ranges of prices that fall in between values that line up precisely with the forecast errors that the Department has made in the past.

All backward-looking approaches are sensitive to the adequacy of the available history of forecast errors. Small samples reduce reliability, since they may not be large enough to provide an adequate basis for the construction of empirical densities (Taylor and Bunn, 1999). Moreover, no backward-looking method has the capacity to reflect expectations about market conditions that may be uncorrelated with past price behavior—they all assume that the error distribution is time invariant.

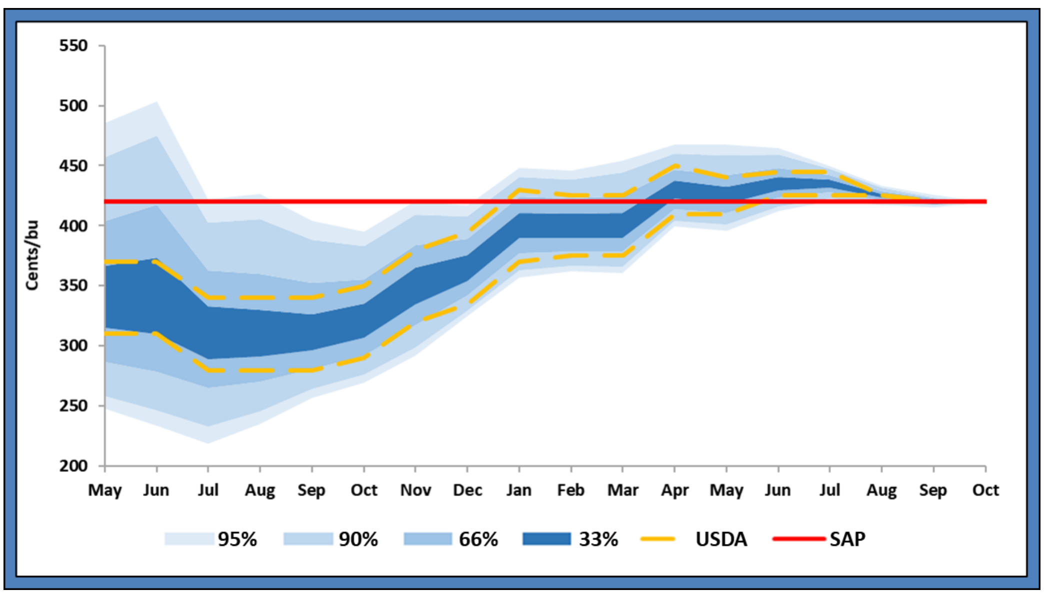
Forward-Looking Approach

Forecast densities can also be constructed using forward-looking information, for those commodity markets that supply it (or perhaps even for smaller markets that do not, as long as their features are relatable enough to larger markets that do; this is analogous to, for example, cross-hedging sorghum risk using the liquid corn market derivatives (CME Group, 2015)). Liquid and active futures and options values reveal the market's expectations about the first and second moments of a given commodity's expected price distribution.[3] Futures prices represent the market's risk-neutral expectation about future commodity prices,[4] while options premia—whose value is based in part on the expected variance of the underlying futures contract price—can be inverted to solve for market-implied volatilities using an option pricing model, as in Black (1976). The resulting forward-looking price density forecasts respond dynamically to changes in the option-implied volatilities: they narrow or widen with the updates to market uncertainty that are embedded in options prices.

This market-sensitive feature is not possible when using backward-looking methods, yet its impact can be substantial. In July 2007, for example, the implied volatility observed for corn contracts was among the highest observed over the previous ten years. As a result, the *ex-ante* forecast density we estimate using that level of uncertainty is fairly wide, as shown in Figure 1a. The benefit of incorporating option-implied volatility, at least for that specific month, is better grasped when considering that the final SAP realized in the 2007 marketing year was well outside the kernel-based backward-looking density shown in Figure 1b; in other words, the backward-looking method missed completely. In the same vein, the price spike later in Fall 2007 was not anticipated by USDA analysts (i.e., note how the dashed yellow range in Figure 1b is too low), and the spike's effect on price was so substantial that the resulting forecast error was far larger than any forecast error those analysts had made at the same point in the forecasting cycle in *any* of the previous 26 years. In contrast, the forward-looking density, while placing a low probability that corn prices might move that high, nevertheless assigned a positive probability to the eventual realized SAP value. In short: options prices reflect traders' concerns about future volatility that can help predict possible future SAP paths.

Figure 1
Forecast Densities of the Corn Season-Average Price over 2007/08

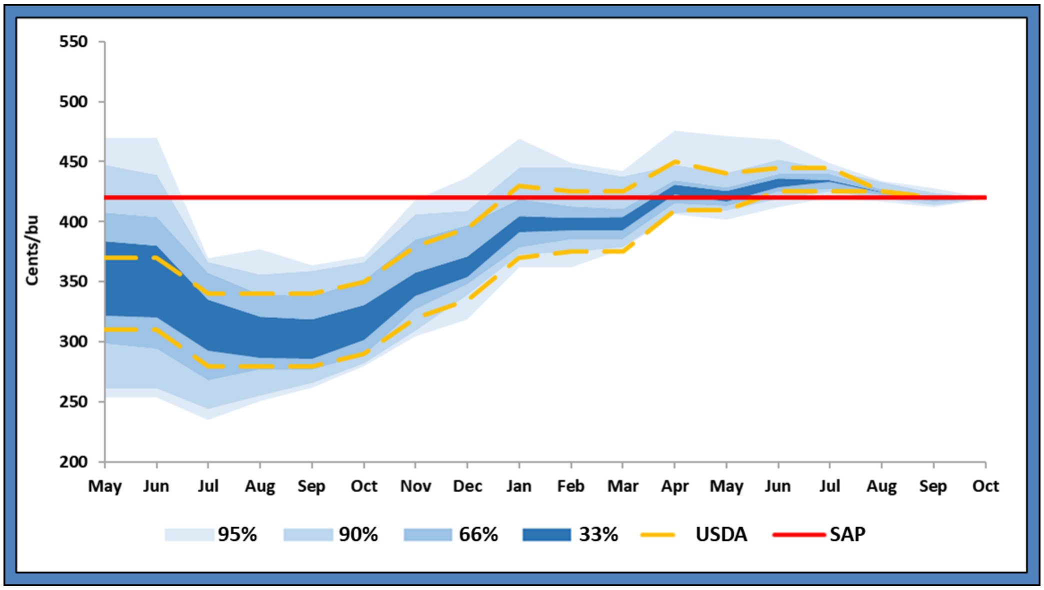
1a. Forward-Looking Forecast Intervals at Various Confidence Levels



Source: Author calculations based on USDA and Chicago Mercantile Exchange (CME) Group data.

Notes: Shaded regions represent *ex-ante* predictions of confidence intervals for the marketing year's season-average price (SAP), at each forecast step. "USDA" is the interval predicted by USDA in the WASDE report. This figure is reproduced with permission from Wiley.

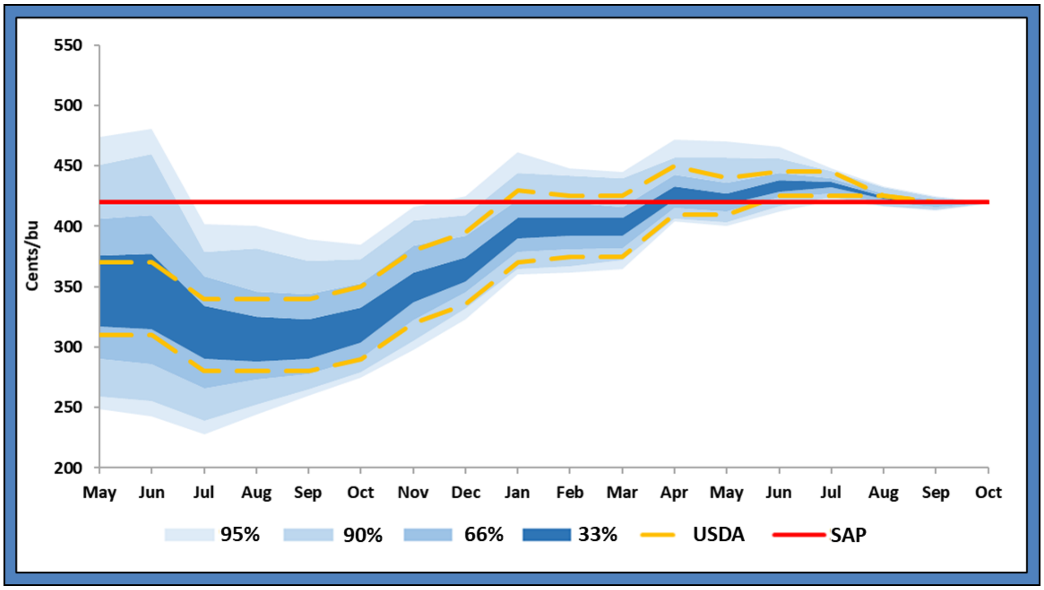
1b. Backward-Looking Forecast Intervals at Various Confidence Levels



Source: Author calculations based on USDA and CME Group data.

Notes: Shaded regions represent *ex-ante* predictions of confidence intervals for the marketing year's season-average price (SAP), at each forecast step. "USDA" is the interval predicted by USDA in the WASDE report. This figure is reproduced with permission from Wiley.

1c. Composite Forecast Intervals at Various Confidence Levels



Source: Author calculations based on USDA and CME Group data.

Notes: Shaded regions represent *ex-ante* predictions of confidence intervals for the marketing year's season-average price (SAP), at each forecast step. "USDA" is the interval predicted by USDA in the WASDE report. This figure is reproduced with permission from Wiley.

Composite Approach

Forecast densities generated *via* forward- and backward-looking approaches can be combined, so that features of both are incorporated into the process. This is a useful step if backward-looking information can add explanatory power to the forecast of average commodity prices across the United States *at the farm level*, an important concern given that the prices for options on futures contracts traded in Chicago represent uncertainty about cash-market prices in a single location at a single delivery date. That is, futures and options-on-futures prices do not address spatial basis risk, i.e., the possibility that futures and farm-level prices might not move perfectly together. We therefore create composite forecast densities by applying equal weights to both forecast methods at every step over the period of observation. In effect, our composite density is a simple average of both original densities. To gauge the benefits of including features of both original methods into a single density, we include that simple composite forecast in our evaluation.

Comparing the Backward-Looking, Forward-Looking, and Composite Approaches

Standard evaluation techniques for probabilistic forecasts focus on *sharpness* and *calibration* (Kling and Bessler, 1989; Gneiting *et al.*, 2007), which represent, respectively, the ability of the model to place a high-density value at the eventual realized price, and the similarity of the forecast densities to the true expected price density. Sharpness and calibration can be jointly measured using scoring rules (Gneiting and Raftery, 2007), while calibration is generally assessed via the probability integral transform (Diebold *et al.*, 1998; Berkowitz, 2001) or coverage tests for selected intervals (Christoffersen, 1998). Two popular examples of the former include the logarithmic score (calculated as the logarithm of the forecast density evaluated at the realized outcome) and the continuous ranked probability score (CRPS), which measures the divergence of the forecast distribution from a perfect forecast with a probability mass located at the realized observation (Gneiting and Raftery, 2007).

The SAP forecasting cycle is 18-steps long, further ahead in time than forecasts considered in many other contexts. Longer horizons correspond to higher levels of uncertainty: as a result, we cannot usefully employ log scoring methods (Good, 1952; Bernardo, 1979; Gneiting *et al.*, 2007), since they depend on the logarithm of the value of the forecasted cumulative distribution function at the realized price. In some cases, our forecast densities do not include the realized price, so the value of the respective cumulative distribution function is zero—and of course the logarithm of zero is undefined.

Rather than assigning an arbitrary log score (Boero *et al.*, 2011), therefore, we employ instead the CRPS—a quadratic scoring method that calculates the divergence of each forecasted density from an "ideal forecast" that places all probability mass at the realized price. An important advantage of the CRPS is that, unlike the log score, it awards forecasts that place more probability near (but not at) the realized value (Gneiting and Raftery, 2007). Densities with lower CRPS are preferred, and the units of the CRPS are the same units of the original forecast: in our case, the price of each agricultural commodity is expressed in cents per bushel.

From 1995/96 to 2015/16, the USDA made a total of 376 SAP forecasts for corn. To compare approaches, we estimate SAP price densities via forward-looking, backward-looking, and composite methods, using only information that would have been available to USDA forecasters at the time. To represent USDA's forecast policy, we include the traditional intervals as well as the point forecasts as candidate models. For the former, in the absence of any public information about USDA analysts' preferred functional form (Vogel and Bange, 1999), we assume a uniform probability distribution over the published interval; for the latter, we assume that the midpoint of an interval is USDA's price forecast. We judge sharpness and calibration of each approach according to the CRPS. Forecasts that produce lower CRPS values are preferred; following Colino *et al*. (2012) and Etienne *et al.* (2019), we compare the average scores produced by models at each forecast step using modified Diebold-Mariano tests (Harvey *et al*., 1997). To further evaluate the sample-wide calibration of forecast models, we explore their coverage at several selected confidence levels, i.e., whether the model-predicted level of uncertainty at forecast time matched the realized uncertainty over the period of observation; and, like Isengildina-Massa *et al*. (2011), we assess their statistical equivalence using unconditional coverage tests (Christoffersen, 1998).

Discussion of Model Performance

Table 1 compares the performance of all candidate corn models at each forecast step on the basis of CRPS. Outside of a handful of exceptions, probabilistic models produce lower CRPS values than either of USDA's methods. Indeed, for the clear majority of the cycle, the scores the USDA approaches produce are significantly worse. As expected, point forecasts, in particular, tend to produce very high average CRPS: they place all the probability mass on a SAP that is often distant from the realized value. Only in the late *post*-harvest period (i.e., after most of the crop has generally been marketed at known prices), does the relative precision of the point forecast method improve. USDA's interval method, which the Department used prior to switching to point forecasts in 2019, doesn't perform much better.

Table 1
Average CRPS for Out-of-Sample Corn Season-Average Price Forecasts over 1995/96 – 2015/16, by Model

	Forecast	N	Forward	Backward	Composite	USDA	Point
Pre-Harvest	May	21	39.5	40.7	39.9	47.3	55.0
	Jun	21	40.4	42.3	41.2	49.0	56.6
	Jul	21	33.2	34.2	33.6	38.5	46.0
	Aug	21	32.9	33.7	33.2	37.9	45.6
	Sep	21	29.8	29.7	29.6	33.4	42.0
	Oct	20	21.0	21.7	21.3	23.1	30.9
Post-Harvest	Nov	21	13.7	13.9	13.7	13.5	17.2
	Dec	21	9.8	10.3	10.0	9.7	12.7
	Jan	21	7.4	7.5	7.4	7.3	9.9
	Feb	21	6.1	6.4	6.2	6.2	8.5
	Mar	21	4.8	4.9	4.8	4.9	6.4
	Apr	21	4.3	4.2	4.2***	4.4	6.0
	May	21	3.6	3.5	3.5***	3.5	4.9
	Jun	21	3.8	3.8	3.7***	3.8	5.4
	Jul	21	1.8***	2.1	1.9	1.9	2.4
	Aug	21	1.3***	1.5	1.4	1.5	1.8
	Sep	21	0.7***	0.9	0.8	0.9	0.9
	Oct	20	0.2***	0.2	0.2	0.2***	0.2***

Source: Author calculations based on USDA and CME Group data.

Notes: A U.S. government shutdown in October 2013 curtailed publication of the WASDE report that month, so one new crop and one old crop forecast is missing from the 21-year forecast sample. “Interval” represents a density model that assigns uniform probability over USDA’s published intervals. Average CRPS scores at each forecast step are reported in cents/bushel. Lower CRPS values are preferred; the lowest score at each forecast step is shaded. Significance of modified Diebold-Mariano (MDM) tests between the lowest CRPS value and the model with the next lowest value at each step are indicated by asterisks: *** represents the 1% level, ** the 5% level, and * the 10% level. The null hypothesis of the MDM tests assumes equality of forecast performance. This table is reproduced with permission from Wiley.

In sharp contrast, CRPS results shine a favorable light on our models that include forward-looking information: forward-looking or equal-weight composite models produce the lowest average score at almost all forecast steps. In some cases, these scores are significantly lower than the next-best score, according to modified Diebold-Mariano tests. And forward-looking models tend to perform best at two times: *pre*-harvest, when option-implied volatility helps characterize the uncertainty about crop conditions and their implications for farmgate prices; and then again very late in the marketing cycle, well after the harvest came in.

Backward-looking forecast errors seem to hold the most predictive value in the *post*-harvest December-June period: that part of the year is when their inclusion in the form of a composite model produces lower average CRPS. Put differently, including the profile of past USDA forecast misses starts to improve on our futures-based approach to describing uncertainty expectations about farm-level corn prices just as about half of the crop has been marketed. This finding is consistent with the idea that, although futures and options markets can produce efficient forecasts for commodity prices in a single market at point in time, they do not fully represent uncertainty about the average price that farmers will get paid across the vast United States—historical USDA errors can help produce better density forecasts at certain steps. By the late-forecasting-cycle period, our forward-looking models again tend to produce the lowest average CRPS for both commodities. Although statistically significant, these improvements are fairly small in absolute terms; moreover, the utility of those forecasts is likely lower than those made before the harvest, and than those made before the bulk of the crop has been marketed.

Were USDA to publish intervals around its SAP forecast, the Department might choose among those depicted by the density forecasts in Figure 1. Table 2 reports hit rates achieved by each model (except the Point Estimate approach, which does not produce intervals) at each of those confidence levels, for the *pre*-harvest and *post*-harvest period, respectively, as well as the results of unconditional coverage tests that assume equivalence as the null hypothesis. Table 2 also reports the average size of those intervals in cents per bushel. Though it is not *always* the case, models that produce wider average intervals tend to achieve higher hit rates; better coverage is indicated by matching an interval's hit rate to its *ex-ante* confidence level.

Table 2

Corn Season-Average Price Forecast Hit Rates and Average Size (in cents/bushel) for Select Confidence Intervals Based on Out-of-Sample Density Forecasts over 1995/96 – 2015/16, by Model

Confidence Level	N		*Pre*-Harvest Period: Forward	Backward	Composite	USDA	N	*Post*-Harvest Period: Forward	Backward	Composite	USDA
95%	125	Hit Rate	92.8%	78.4%***	84.8%***	47.2%***	251	96.0%	95.6%	96.8%	82.5%***
		Avg. Size	203	175	187	56		43	54	49	27
90%	125	Hit Rate	82.4%***	78.4%***	80%***	40.8%***	251	94.4%**	92.4%	94%**	81.7%***
		Avg. Size	172	150	160	53		37	41	38	26
67%	125	Hit Rate	64.8%	61.6%	62.4%	32%***	251	80.5%***	70.1%	75.7%***	71.7%***
		Avg. Size	101	92	96	41		23	20	22	20
33%	125	Hit Rate	29.6%	30.4%	28.0%	12%***	251	56.6%***	48.2%***	52.2%***	56.2%***
		Avg. Size	46	48	47	22		11	9	10	11

Source: Author calculations based on USDA and CME Group data.

Notes: "Hit rate" represents the percentage of realized season-average prices that fall inside the *ex-ante* confidence intervals produced by each model, while "Avg. Size" is the mean range of the interval. Significance of unconditional coverage tests that compare observed hits to the specified confidence level (where the null hypothesis is that the hit rate and the target confidence level are equivalent) is indicated by asterisks: *** represents the 1% level, ** the 5% level, and * the 10% level. This table is reproduced with permission from Wiley.

Coverage tests reject every confidence interval produced by the USDA's model: over time, it produced very low hit rates (and relatively small intervals) at each confidence level. Other models in the table produce far fewer test rejections than the USDA's approach.

In the *pre*-harvest period, our corn forward-looking model has just one test rejection (at the 90% confidence level), and the backward-looking and composite models only have two. In the *post*-harvest period, our forward-looking and composite intervals have three test rejections: each produces too-high hit rates at every confidence level in the table besides 95%.

The backward-looking model has the fewest total coverage test rejections, but these are clustered early in the forecasting cycle—when those intervals should be the most valuable to consumers. In contrast, the forward-looking model's coverage misses (while slightly more numerous) are clustered in the *post*-harvest period, when they are likely to be less costly.

Conclusions

From 1977 through 2019, the USDA produced forecasts of the average price that farmers should expect to receive over the course of a marketing year for major domestic crops. Until April 2019, to indicate uncertainty about the forecast, the Department's analysts placed symmetric intervals around each forecasted price; these intervals narrowed over the course of the forecasting cycle and eventually collapsed onto the single point. The USDA, however, did not indicate the degree of statistical confidence attached to those intervals, so they were not very (if at all) meaningful. In May 2019, the Department altogether abandoned intervals in favor of a single point estimate.

In this *GCARD* article, we reference research we published in the *American Journal of Agricultural Economics* (Adjemian *et al*., 2020) to describe the benefits of probabilistic forecasting and evaluate three approaches to making out-of-sample density forecasts of the season-average price for corn. These densities would permit the USDA to construct empirically-based price intervals at a range of confidence levels. Because consumers of the SAP forecasts include market participants and government agencies responsible for planning their program outlays, bounding the uncertainty around farmgate commodity prices using any or all of these densities would offer far more information than a mere point estimate, providing a richer profile of price expectations. Every density model that we estimate (using backward- and/or forward-looking information) is better than the USDA SAP forecast methods across the bulk of the forecasting cycle, both in terms of locating a greater level of probability near the *ex-post* realized SAP, and in terms of coverage tests at selected confidence levels. And, since they are provided in a probabilistic format, every density model produces richer forecast profiles that can be better utilized by forecast consumers, compared to a simple point forecast or to a range estimate without confidence figures.

Each density approach has its own advantages and drawbacks. Because it is constructed using historical USDA forecast errors, the backward-looking model is easy to estimate. It also does not require that a related derivatives market exist or work well. And although it is generally not favored according to CRPS, the *post*-harvest confidence intervals that it produces are reasonably accurate. The forward-looking and composite models that we estimate require information from derivatives markets, and are constructed using the market's expectation of future price volatility implied by commodity options premia. Their densities and confidence intervals therefore adjust dynamically to changes in market sentiment, and intuitively they can reflect expected volatility better than historical models. Indeed, we show that widely-used calibration evaluations tend to favor these models which, on average, place a higher amount of probability closer to the realized SAP. Including forward-looking information, in other words, is valuable when it matters the most—and it is especially useful in volatile or uncertain times (like the situation depicted in Figure 1).

Endnotes

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1 For example, over the 17 years from May 1989 to May 2006, the USDA's first interval prediction for the average price paid to farmers for corn harvested in the ensuing Fall was always 40 cents.

2 Prominent examples of fan charts include those published quarterly by the Monetary Policy Committee (MPC) of the Bank of England, illustrating its expectations about output growth, inflation, and unemployment in the United Kingdom. In April 2017, the U.S. Federal Reserve Bank began issuing fan chart projections for all those variables in the United States, as well as for the target federal funds rate (FOMC, 2017).

3 A commodity option contract represents the right, but not the obligation, to assume a (long or short, depending on whether the option is a call or put) position in a specified commodity futures contract at an agreed upon price. The value of that right is a function of how uncertain the future price is, i.e., of the forward-looking price volatility.

4 Some economists argue that a commodity futures price represent its expected future price plus a risk premium for speculators (see, *e.g.*, Keynes, 1930). This claim has received mixed empirical support in the literature, particularly as it relates to grains (Hartzmark, 1991; Frank and Garcia, 2009; Fishe and Smith, 2012). We do not consider risk adjustments to the determination of implied volatilities in this analysis, but intend to explore them in future work.

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He has written numerous articles on the causes and consequences of volatility, the electronification and financialization of commodity markets ("who trades what, how, when, and does it matter?"), information economics, and international financial economics. He is an Associate Editor of the *Journal of Commodity Markets*. His work has appeared in top generalist journals such as the *Journal of Financial Economics*, the *Journal of Financial and Quantitative Analysis*, and the *International Economic Review*; in top field journals such as the *American Journal of Agricultural Economics* and the *Energy Journal*; and in numerous other academic journals and in books. His current work deals with commodity price volatility, the organization of derivatives markets and their microstructure, and investor protection.

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Searching for Asymmetry: The Case of Crude Oil

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Dr. Bluford Putnam, Ph.D., Chief Economist at the CME Group, presenting at a J.P. Morgan Center for Commodities' international commodities symposium held at the University of Colorado Denver Business School.

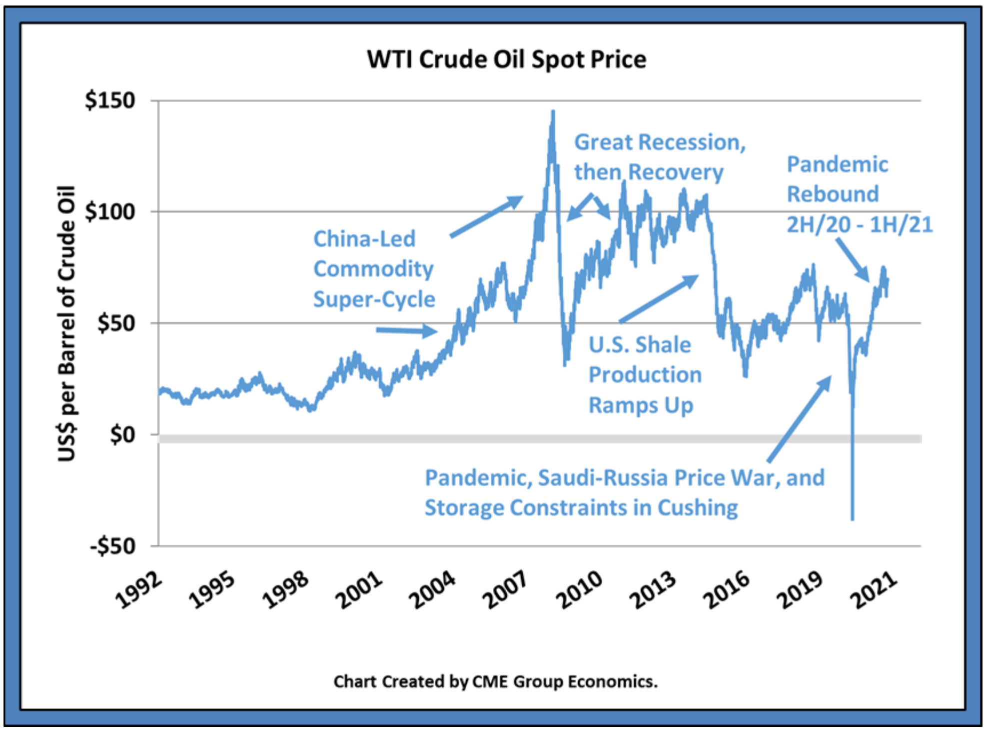
As an analytical approach, one can gain considerable insights into market behavior by searching for asymmetry and irregularities in patterns in the price discovery process. From an informational content perspective, the current price is just the tip of the iceberg in terms of inputs into the analytical process. Here we want to take the case of the crude oil market as an example, and work through what may be gleaned from going beyond the current price, to study the forward maturity curve from the futures market, the volume and open interest patterns in options trading, approaching implied volatility from different perspectives, and creating hypothetical risk-return distributions to enhance the analysis.

Markets are complex systems with a myriad of feedback loops. Production is adjusted, demand shifts, transportation challenges may come and go, inventories go up and down, and the political environment evolves, in addition to other factors. While analysts monitor all these developments as fundamental drivers of the market, in a complex system we also need to understand how market participants are reacting. So, here, as we work through the different metrics that may tell us something about market behavior, we are always searching for asymmetrical or irregular patterns that may provide clues about the debates swirling inside market activity and that may help us improve our risk management processes.

Appreciating the Events that Move Markets

Tracking patterns in the price of a commodity, such as crude oil, can highlight the magnitude of the impact of key fundamental drivers on market activity. During calm times with relatively small price moves, it can be very hard to tease out of the price data the impact of any given factor when the evolution of the different influential factors is slow moving and multiple factors are in play simultaneously. Larger price irregularities offer the opportunity to better appreciate which factors are the key drivers and to gauge whether these factors are increasing or decreasing in influence on the price. Figure 1 provides an illustration of what was driving large price moves coming from such factors as demand growth from China, the financial panic that led to the Great Recession of 2008-09, the explosion of shale oil production in the U.S., the onset of the pandemic of 2020 that led to a production battle between Saudi Arabia and Russia, and later the demand increases with the rebound from the pandemic.

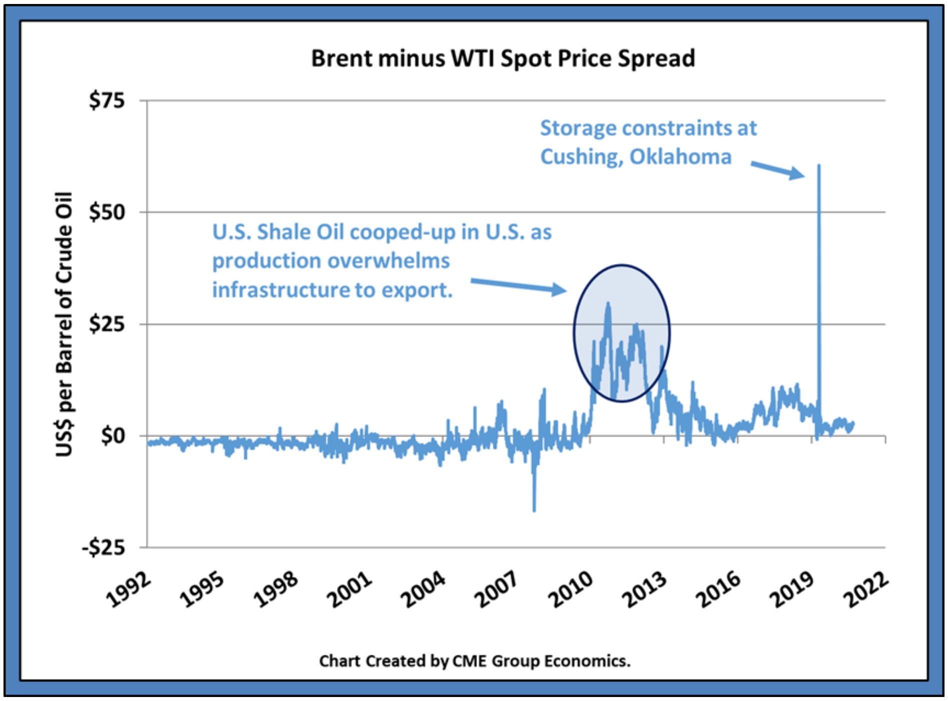
Figure 1



Source: Bloomberg Professional (WTI = USCRWTIC).

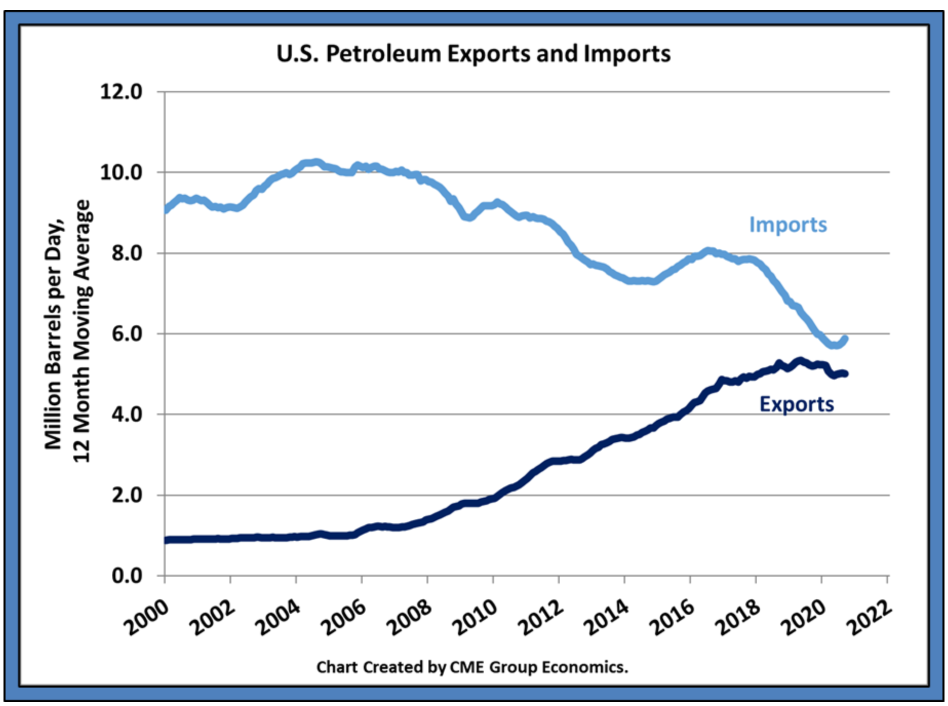
Monitoring the price movements of adjacent markets, such as comparing the price spread between Brent crude oil and West Texas Intermediate (WTI) crude oil, can also yield valuable insights when patterns become irregular or shift gears. Figure 2 on the next page highlights the widening of the spread between Brent and WTI crude oil during the period when U.S. shale production was soaring, but the domestic infrastructure was not ready to switch to exporting oil. During this period, roughly 2011 into 2013, U.S. oil production was cooped-up domestically so prices for WTI were lower than for Brent. When the U.S. was able to start exporting oil, as shown in Figure 3 also on the next page, the markets for Brent and WTI reconnected, and the price spread collapsed.[1]

Figure 2



Source: Bloomberg Professional (Brent = EUCRBRDT, WTI = USCRWTIC).

Figure 3



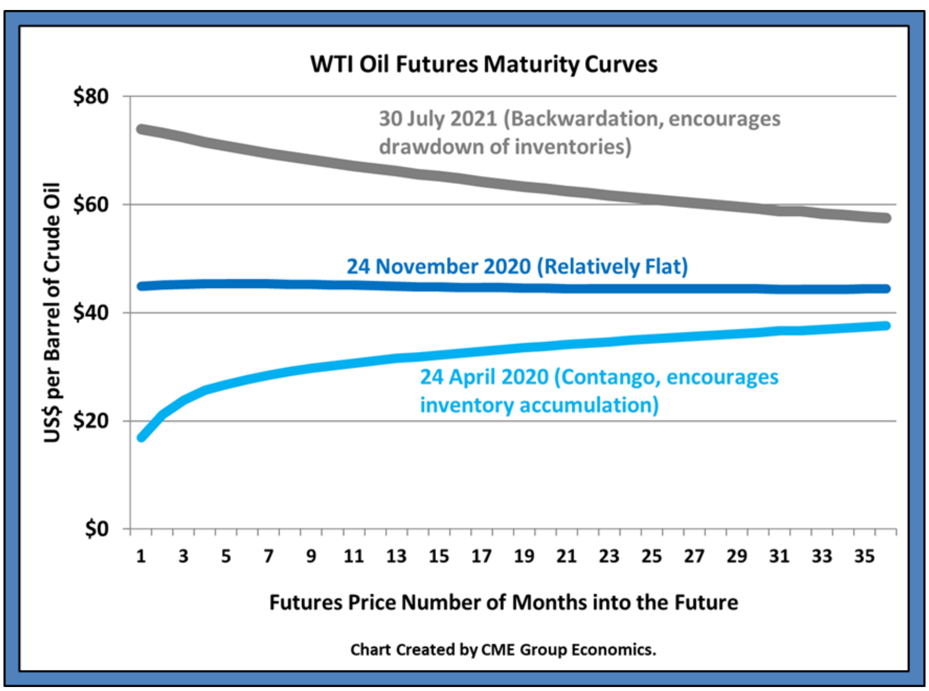
Source: Bloomberg Professional (DOEBCEXP, DOCRTOTL).

Implications from the Shape of the Futures Maturity Curve

Crude oil futures markets provide some incredibly important information about how the price discovery process works for the risk management of oil transactions many months and years forward in time. In particular, the shape of the forward maturity curve can be especially enlightening. Backwardation occurs when the nearby futures price is higher than prices farther out into the future. Contango occurs when the nearby futures price is lower than prices farther out into the future. When contango is relatively severe, this market state can provide incentives for market participants to hoard oil, putting oil into storage now and selling oil forward in the futures market, so long as the calendar price spread more than offsets the costs of storage. Vice-versa when backwardation is severe, there is an incentive to sell oil into the spot market immediately, reducing oil inventories.

The existence of either severe contango or severe backwardation complicates the analysis of changes in the patterns of inventory accumulation as shown in Figure 4. When demand falls sharply, say due to an economic disruption, then one would interpret a rise in inventories as reflecting the magnitude of the fall in demand. This interpretation of magnitude, however, needs to be tempered by studying the oil maturity curve. That is, if the oil maturity curve is in contango, even as demand starts to grow again, inventory may continue to rise so long as storage costs can be more than offset by selling oil forward in the futures markets for a significantly higher price. Equally, the interpretation of falling inventories when there is severe backwardation also needs to be treated with caution. Falling inventories are usually associated with rising demand, but at some point, higher spot prices relative to farther out futures prices create the incentive to sell inventories even if the fundamental demand picture has reversed direction.

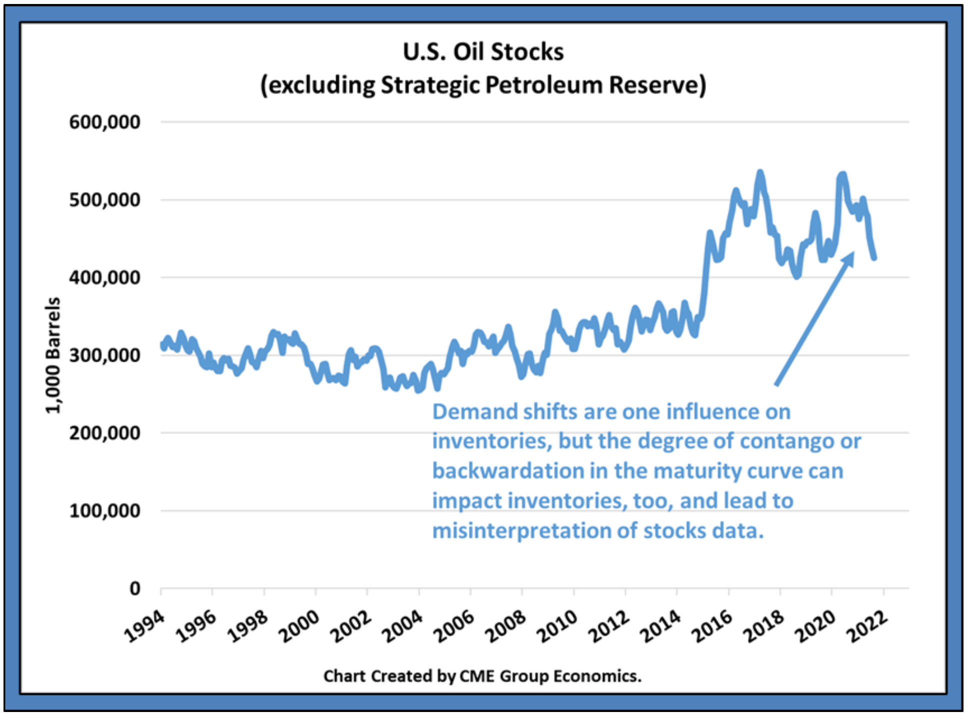
Figure 4



Source: Bloomberg Professional (CL1 through CL36).

Figure 5 shows how backwardation can encourage sales from inventories, even when demand might be slowing, as in July-August 2021.

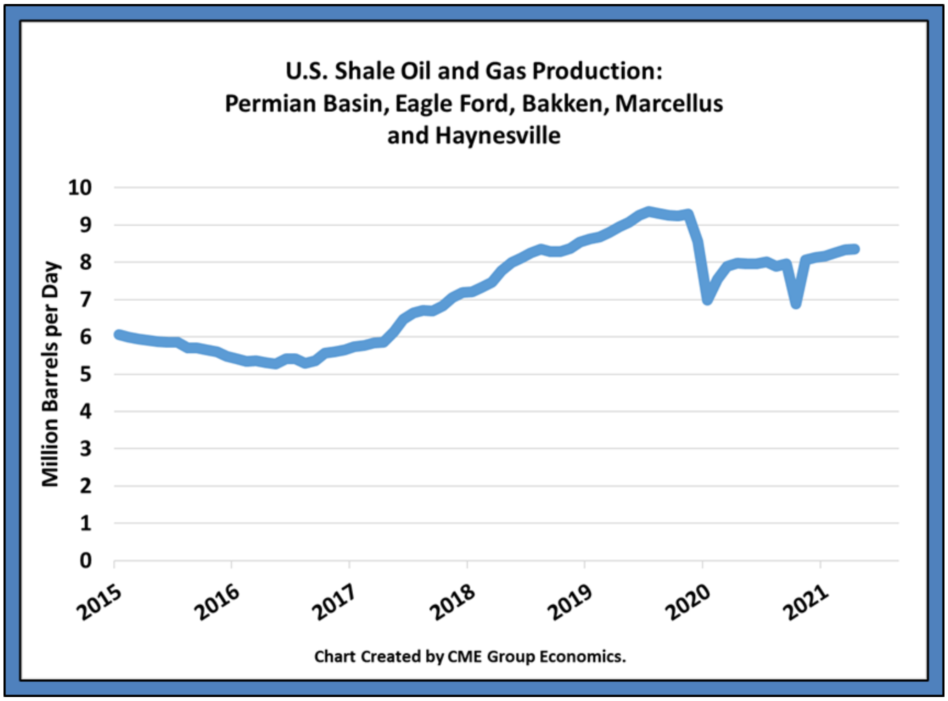
Figure 5



Source: Bloomberg Professional (DOESCRUD).

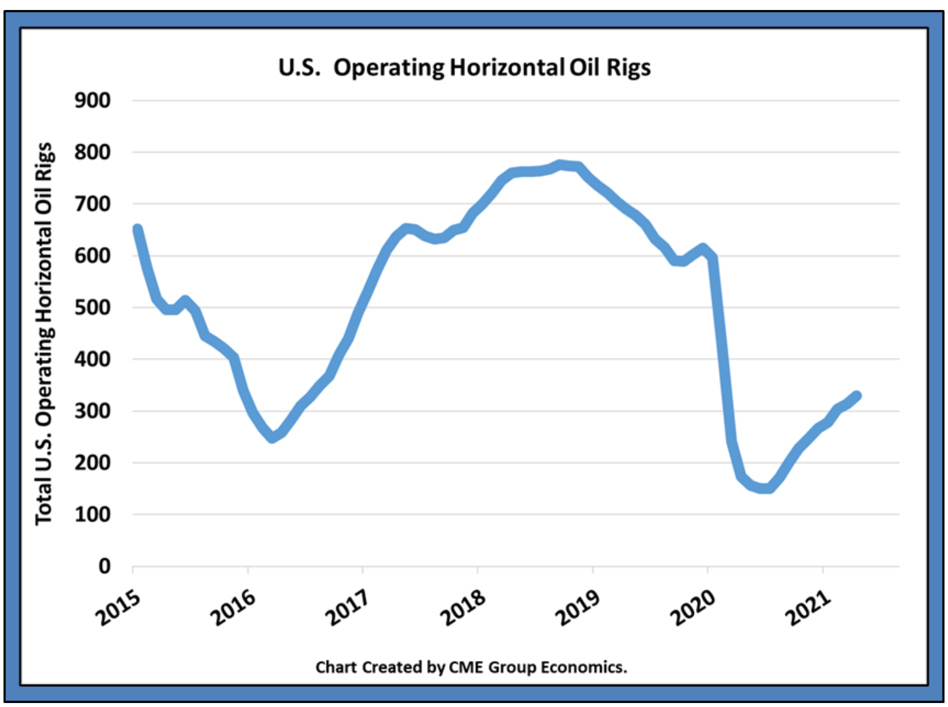
The shape of the oil futures maturity curve also has an influence on the decisions by U.S. shale oil producers to drill new wells or not. During the pandemic rebound period (H2/2020 – H1/2021) as oil prices rallied from their pandemic lows to the $70/barrel territory, there were expectations of sharp increases in U.S. shale oil production. While more wells were drilled and production rose, the production increases were quite modest. See Figures 6 and 7 on the next page. Part of the story can be interpreted through the lens of the oil maturity curve. U.S. shale oil wells have a fairly well-defined life span. The well is drilled and completed, oil starts to flow, peak oil production occurs in 4-6 months, then declines, and the well is shutdown after 18-24 months. From a risk management perspective, the price of oil along the maturity curve during the expected period of production is what matters, not the current spot price. So, severe backwardation works to temper the decision to drill new wells. Other factors also play a role, and the lack of an abundant availability of financing for new wells also appeared to slow the rebound in shale production even as the spot price of oil rose well above estimated break-even production costs. That is, lenders are also studying the oil futures maturity curve to assess appropriate risk management strategies.

Figure 6



Source: Bloomberg Professional (USPSTTPO).

Figure 7



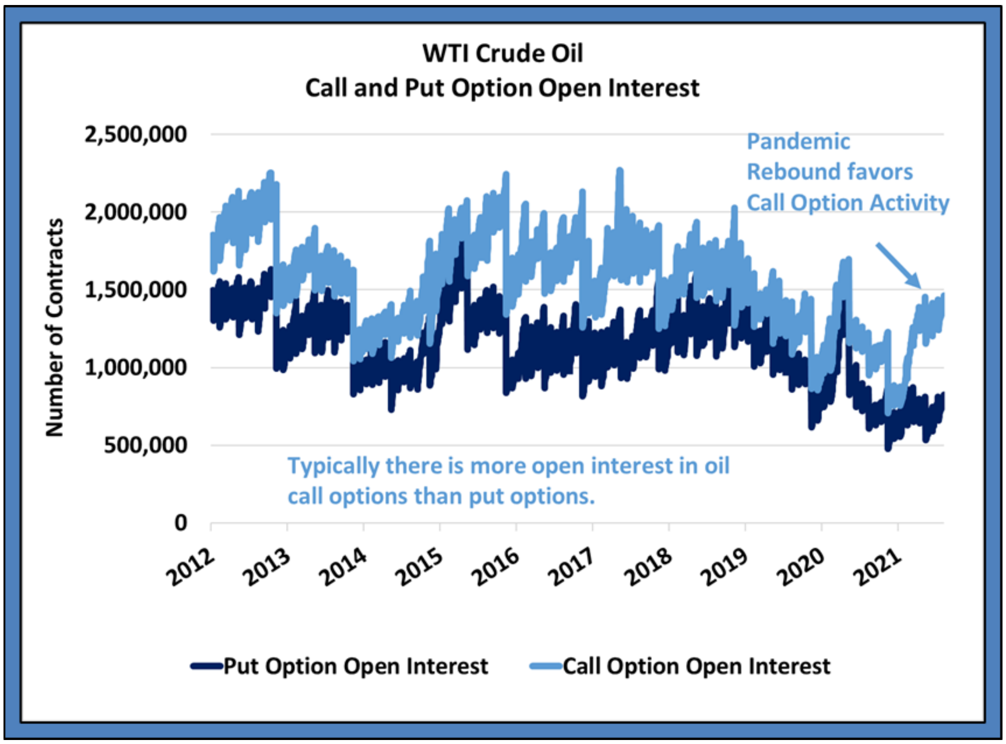
Source: Bloomberg Professional (USPSTTHO).

Changing Patterns of Trading Volume and Open Interest in Options Markets

Moving away from price metrics, one can gain additional insights into market behavior from studying trading volume and open interest in the options markets. Open interest is the quantity of contracts that are outstanding at the end of a given trading day. Trading volume is the number of transactions that occurred during the day. Both are worthy of examination.

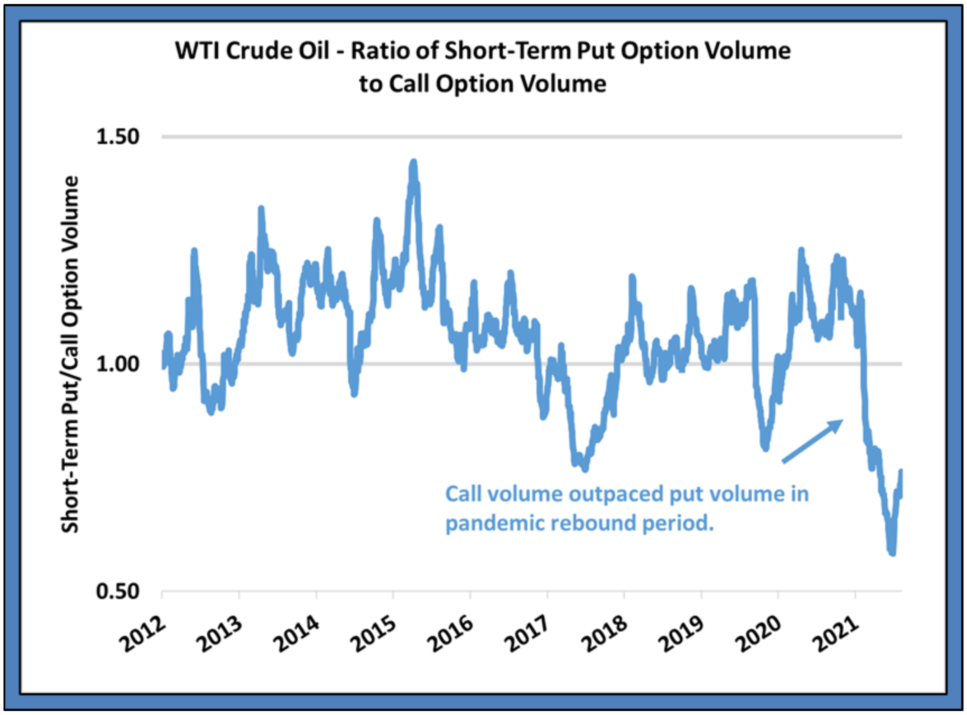
Our focus is on options markets because different trading activity in put options compared to call options can tell us which side of the market is getting the most attention; see Figure 8. This type of asymmetry can yield some interesting insights for risk management.

Figure 8



Source: CME Market Sentiment Meter (CLLO).

Figure 9



Source: CME Market Sentiment Meter (CLLO).

The pandemic rebound period (H2/2020 – H1/2021) can again serve as a case in point. Options themselves are asymmetric in their return profiles. Call options provide purchasers (i.e., long a call option) with a limit to the downside risk while providing increasing rewards when prices rise. Sellers of call options (i.e., short a call option) are essentially providing insurance (e.g., receiving a premium) against a price rise, and they can lose their premium and more if the price rise is substantial. In the U.S. WTI crude oil market for options on futures contracts, it is typical for call options to have more open interest than put options, so we are looking for changes from the usual pattern. During the pandemic rebound period, as oil prices were rallying from their low point in April 2020, call options saw substantially elevated trading activity and open interest compared to put options; see Figure 9. The elevated risk management activity on the call side of the options market can be interpreted as market participants focusing on the potential for further price increases, with considerably less attention on the possibility for price declines. A reversal of the volume and open interest trends can also be interpreted as confirmation that the market is reaching a more balanced supply-demand state in which price rises or declines are again viewed symmetrically. This information about a mismatch in put versus call options volume should not be interpreted as a directional price expectation, as one must remember that there is a buyer for every seller.

Also, studying the volumes and open interest for specific option strike prices can be informative. Starting in March 2021, and lasting for several months, there was a spike in the open interest associated with WTI crude oil call options with strike prices at $100/barrel or higher. At the time, a $100/barrel strike price was some $30 to $40 above the spot price (i.e., way out-of-the-money), so this was another indicator of the asymmetric price expectations in the oil market, which generally are temporary or short-lived, as the price either continues its upward momentum or it stalls out and market behavior shifts again in response.

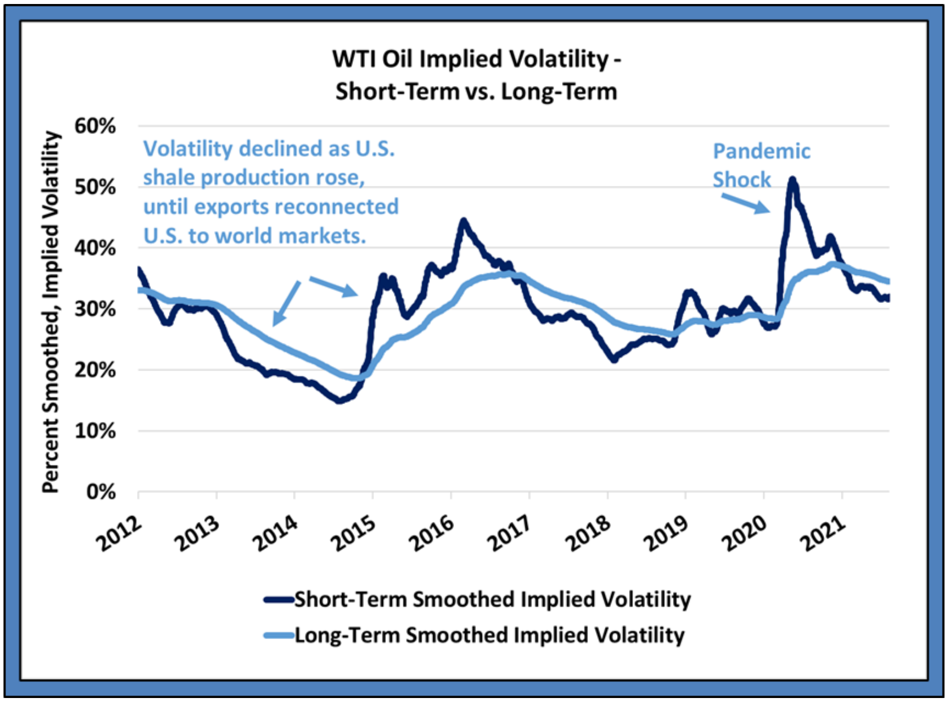
Analyzing Implied Volatility from Multiple Perspectives

Aside from looking at put and call options volume and open interest, options markets are commonly associated with providing a view on future volatility. We study both historical volatility and implied volatility where volatility is measured as the standard deviation of daily percentage price change movements, and typically is reported with an adjustment to annualize the daily standard deviation. Implied volatility is derived by using an options pricing model, such as Black-Scholes-Merton, to backout the volatility assumption that is embedded in the price of the option (Black and Scholes, 1973; Merton, 1973).

Implied volatility is often considered to reflect a pattern of mean reversion. That is, a period of elevated implied volatility will be followed by lower implied volatility. This can be observed in Figure 10 on the next page, which compares a measure of short-term implied volatility with a long-term measure. The pattern of mean reversion is clear, with the critically important caveat that when implied volatility moves higher and then later reverts, it does not always tend go back to the previously lower level of volatility but finds a new valley. For example, the U.S. shale oil revolution initially lowered implied volatility in the WTI crude oil options markets until rising U.S. exports reconnected WTI to the rest of the world. Implied volatility rose, and it never came back down to the lowest levels of volatility previously observed. Ditto for the pandemic shock that raised implied volatility in 2020, yet the subsequent decline in volatility did not go all the way back to previous volatility levels.

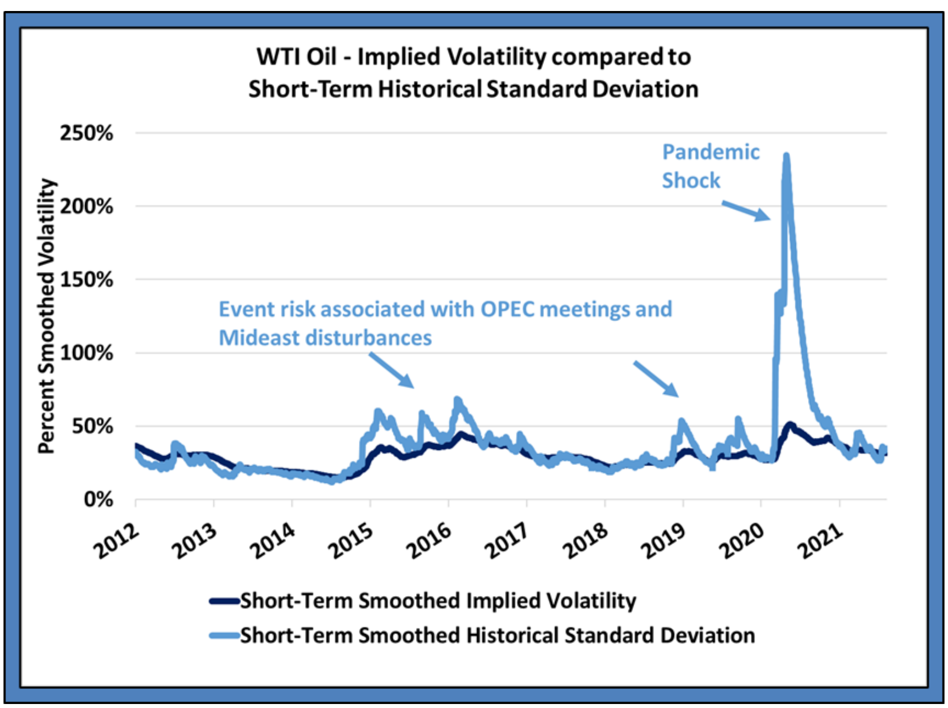
Another useful analytical technique is to look for differences in implied volatility and historically observed volatility. It is typical after a market surprise or shock that raises observed volatility for implied volatility to not reflect the full extent of the spike in actual volatility. That is, the options market is pricing-in the likelihood that after the surprise or shock, market volatility will decline, which is illustrated in Figure 11, also on the next page, comparing implied volatility with historical volatility.

Figure 10



Source: CME Market Sentiment Meter (CLLO).

Figure 11



Source: CME Market Sentiment Meter (CLLO).

There are additional analytical techniques that utilize implied volatility from options markets. We will make some quick comments on a few of the other analytical techniques, mainly to alert the reader that searching for asymmetrical behavior is critical to getting the most insights out of the available market behavior data.

Examining options smiles for skew or asymmetry is a popular technique. At-the-money (ATM) strike prices will usually show a lowered implied volatility than out-of-the-money strike prices for put or call options. It gets interesting when one side of the market – that is, out-of-the-money puts or out-of-the-money calls – display a different pattern or are skewed one way or the other.

One of the analytical techniques of additional interest is to study the option smile or skew at different maturity dates. Here we offer two possible interpretations when the implied volatilities from different strike prices are decidedly different for two different maturity dates. If the closest-in maturity date has the more elevated implied volatility or is skewed materially in one direction or the other compared to the further-out option maturity dates, our perspective is that this case often represents a reaction to a surprise or shock event that just happened. In this scenario, the concept of mean reversion of volatility is dominant.

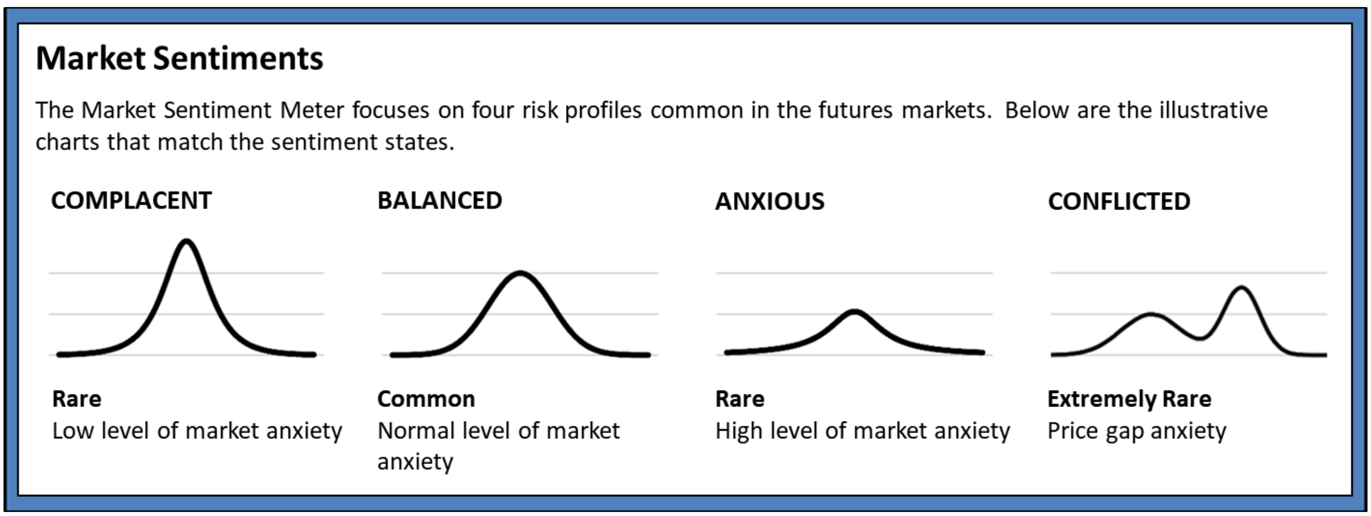
In rare cases, however, the implied volatilities across strike prices for the further-out maturities may be materially elevated relative to the nearby observations. In this scenario, our perspective is that market participants are concerned that there may be an event that might occur in between the maturity dates that could cause an abrupt price change one way or the other. Such a case might occur before an especially pivotal Organization of the Petroleum Exporting Countries (OPEC) meeting, for example. This raises some important issues for interpreting implied volatility. The standard interpretation based on Black-Scholes-Merton option pricing models is that implied volatility represents an expectation about future volatility. But, and it is a big one, Black-Scholes-Merton models have embedded in them the theoretical assumption that there can be no abrupt changes in price. That is, price changes occur in a continuously evolving manner with no price gaps. If market participants expect that there is a meaningful probability of a price gap occurring, then the implied volatility calculated with a Black-Scholes-Merton model will be elevated because it will be pricing both expected volatility *and* the probability of an abrupt price gap. Put another way, when implied volatility is higher in the farther-out option expirations or maturities, then our interpretation is that market participants may be pricing in the risk of an abrupt price gap, but the price move could be up or down.

We can extend this discussion of the embedded assumptions in Black-Sholes-Merton to discuss the assumption of constant volatility as well as imposing a normal distribution on price returns. We want to raise the issue of whether one might calculate implied volatility using a different method that avoids making any assumptions of the underlying probability distribution of market returns or the probability of price gaps or price discontinuities. One such alternative method of calculating implied volatility has been supplied by the CME Group in the form of "Cvol" (CME Group, 2021). Cvol uses the prices for out-of-the-money call options for one side and out-of-the-money put prices for the other side. A distribution is created in which the area under the curve can be interpreted as a measure of the variance, and then be converted into an annualized implied volatility without making any assumptions about the nature of the underlying risk-return probability distribution.

Constructing Hypothetical Risk-Return Distributions

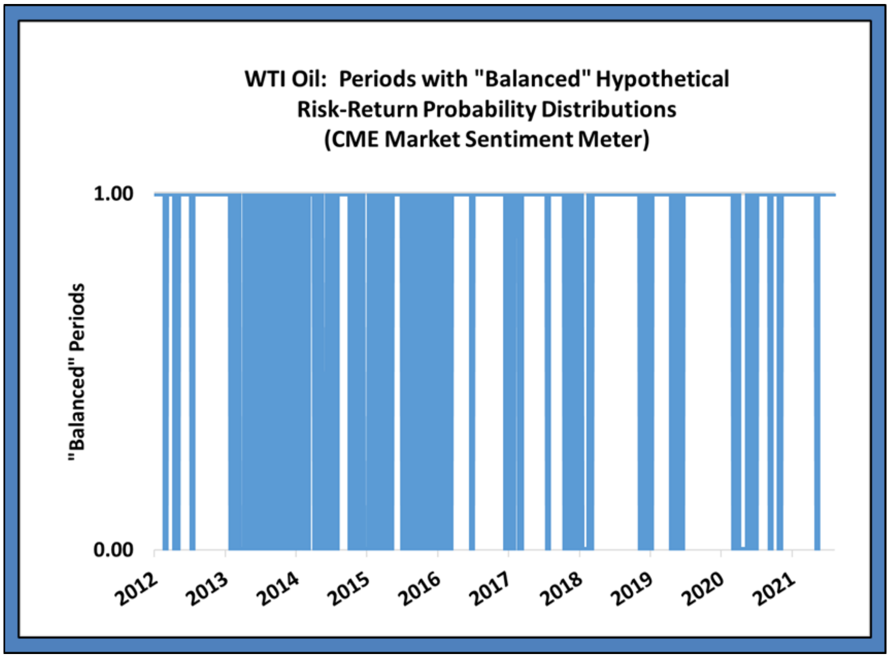
We also can go a step further with our analysis by combining a variety of observed metrics which inform the market behavior of participants and then make some heroic assumptions to create a hypothetical risk-return probability distribution that is completely independent of any assumptions about the shape of the probability distribution. That is, unlike Black-Scholes-Merton which requires a well-behaved single-mode, bell-shaped probability distribution, we can break free of that highly constraining assumption that is clearly at odds with the price patterns observed in the market. Our version is known as the Market Sentiment Meter (or MSM) and is constructed using metrics for implied volatility, historical volatility, intra-day high-low price spreads, and put and call options trading activity, in which two different distributions are created and then combined in a mixed-distribution process. Even if both probability distributions are "normal," the mixture distribution can take on a wide variety of interesting shapes, is not required to be bell-shaped, and can even be bimodal in rare circumstance. In the case of the hypothetical MSM risk-return probability distributions the possible shapes are classified into four sentiment states as show in Figure 12.[2]

Figure 12
Market Sentiment Meter Classification of Sentiment States



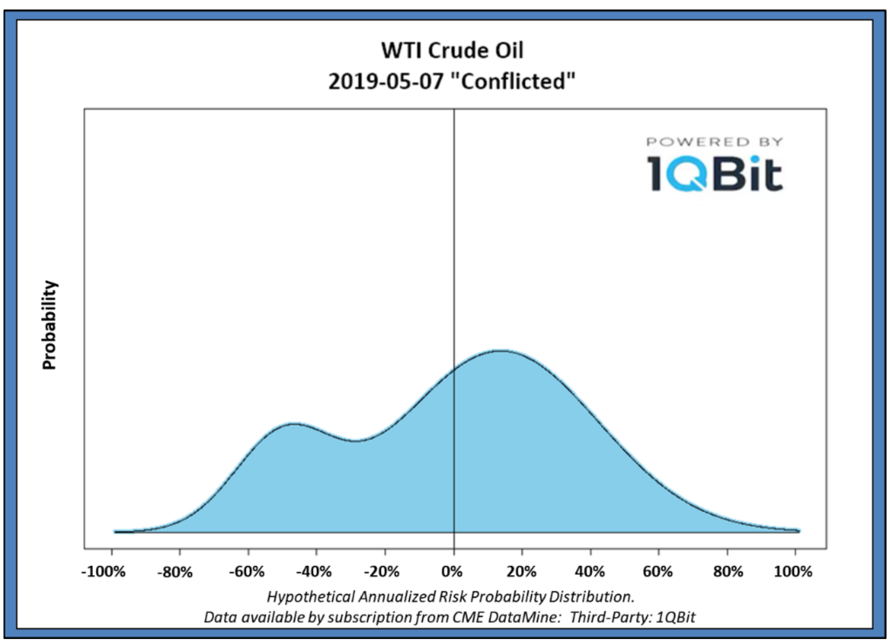
Most of the time, the sentiment state is classified as "balanced," as shown on Figure 13 on the next page. The balanced state is associated with relatively symmetrical market metrics, and thus provides no special insights into risk management challenges.

Figure 13
"Balanced" Sentiment State



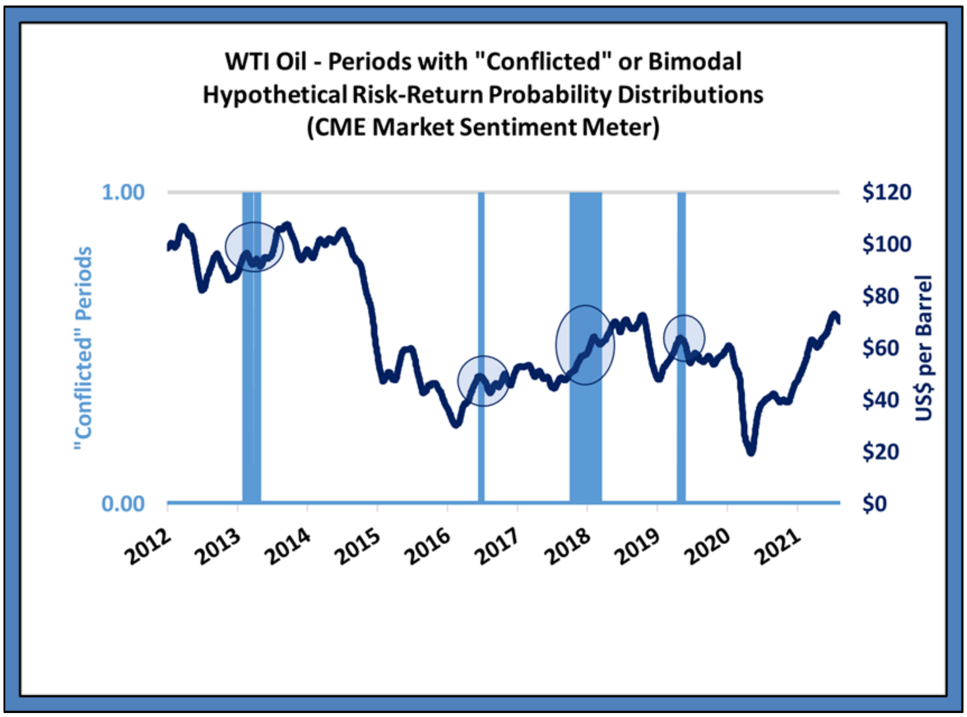
Source: CME Market Sentiment Meter (CLLO).

Figure 14
"Conflicted" Sentiment State



In rare cases, though, a bimodal hypothetical risk-return probability distribution is observed, which is termed "Conflicted." We interpret "Conflicted" distributions as indicating an elevated probability of event risk in which market participants are evaluating two very different scenarios with different outcomes and only one can prevail, an example of which is on the previous page in Figure 14. Our perspective is that when "Conflicted" sentiment states occur, risk managers should be on high alert for abrupt price changes where there is no view of the direction of the change. The "Conflicted" or bimodal case is rare and episodic, as shown in Figure 15. While much more research is needed, non-directional options strategies, such as straddles (i.e., buying ATM puts and calls) may be indicated as possible risk management approaches.[3]

Figure 15



Source: CME Market Sentiment Meter (CLLO).

Bottom Line: Using all the Information to Search for Asymmetries

Our message is that to appreciate all the feedback loops in a complex market system, one needs to pair an array of fundamental data with a wide variety of market behavior metrics to acquire a robust view of what is happening. In this research, we have used the crude oil market to provide a set of metrics and our interpretation of them to illustrate the value of searching for asymmetrical behavior or irregular patterns in the metrics. The current price is merely a starting point for understanding what is driving markets.

Our analytical methods go beyond the current price to also focus on:

- the forward maturity curve from the futures market,
- the volume and open interest patterns in options trading,
- implied volatility for different perspectives, and
- creating hypothetical risk-return distributions to enhance the analysis.

The objective is to enhance our risk management approaches by gaining a more complete appreciation of the activity inside markets that is interacting with the fundamental forces driving markets. We want to leave no information source untouched as we go behind the scenes to analyze complex market behavior.

Endnotes

Dr. Putnam presented on this topic at the JPMCC's 4th Annual International Commodities Symposium during his Industry Keynote speech on August 16, 2021. The Symposium's Program Committee Co-Chairs were Dr. Jian Yang, J.P. Morgan Endowed Chair & JPMCC Research Director and Dr. Thomas Brady, Executive Director of the JPMCC.

Dr. Putnam is a regular contributor to the *GCARD*'s Economist's Edge section. In addition, for further coverage of the crude oil markets, one can also read past *GCARD* articles on this topic.

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.

1 Similarly, as discussed in Till and Eagleeye (2017), by the end of 2013, near-month refinery margins also no longer needed to rally to extraordinary levels to incentivize the transporting and refining of burgeoning domestic crude oil supplies.

2 The classification of market risk profiles into four sentiment states was originally discussed in Putnam (2019).

3 For a statistical analysis of non-directional strategies as applied to equities, see in Kownatzki *et al.* (2021).

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Dr. Putnam is also a member of the J.P. Morgan Center for Commodities' Research Council.

Extreme Price Co-movement of Commodity Futures and Industrial Production Growth: An Empirical Evaluation

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Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3681159

This article studies whether the extreme price co-movement of commodity futures can be exploited to anticipate future industrial production (IP) growth. For this purpose, an empirical model is estimated to derive a measure that characterizes upside and downside price extremes. The derived price extremes are shown to be positively associated with IP growth over the next quarter. The findings further suggest the presence of an asymmetry: the association corresponding to downside extremes is robust whereas that of upside extremes is weaker. The findings reinforce the informational friction theory as well as those financial studies that emphasize downside risk in financial markets.

Introduction

Economists have long recognized that commodity futures prices serve as valuable indicators for goods production as they convey insightful information about the future movement of the real economy. The net economic impact of commodity futures prices is still unclear because, as the informational friction theory of Sockin and Xiong (2015) contends, many different types of shocks (such as in supply, demand, and financial markets) are indeed non-observable to commodity market participants.

Goods producers may perceive an increase in commodity futures prices as signaling a booming economy, that is, revealing an increase in commodity consumption. However, increasing commodity futures prices could lower commodity demand simply because of the standard cost effect. Little is known, however, about the direction and degree to which the especially large ups and downs of commodity futures prices signal subsequent production levels. Understanding this will not only be helpful for goods production planning, financial investment, but is also highly important for regulators wishing to stabilize excessive turbulence from the supply side.

Relevance of the Research Question

The authors empirically examine how *extreme price co-movement* affects industrial production (IP) growth combining the *synchronized* movements and the *large* price changes into one indicator. Assessing these two aspects simultaneously grants this research with two main advantages. First, despite a growing body

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This digest article was edited by Ana-Maria Fuertes, Ph.D., Professor in Financial Econometrics at Bayes Business School, City, University of London (U.K.) and Associate Editor of the GCARD.

of literature with renewed interest in commodity futures markets, the analyses are limited within the scope of individual commodity futures (*e.g.*, Singleton, 2014)[1] or pairwise correlations (*e.g.*, Tang and Xiong, 2012). However, the ability to model a high-dimensional space is essential for understanding the growing integration of commodity futures markets. Second, though widespread co-movement in commodity futures prices can indicate a rising risk in the real economy, only characterizing this phenomenon may be not enough, as it is natural that commodity futures prices tend to move together due to some common fundamentals as well as financial trading factors (Pindyck and Rotemberg, 1990). In contrast, the co-moving tendency of large price changes, particularly over a longer period (such as one year), are generally thought to indicate big shifts in the underlying macro fundamentals or an accumulation of extreme risks that would further transmit to spot markets (Cheng and Xiong, 2014; Sockin and Xiong, 2015). In this regard, modeling synchronized large price changes appears to be a more promising representation of commodity price risks that indicate the direction of the real economy.

Technical Motivation in Modeling the Extreme Price Co-Movement of Commodity Futures

To measure the extreme price co-movement of commodity futures, not only the univariate distributions of each commodity futures return must be accurately modeled but also their joint distribution. The objective is to capture the dependence structure among different commodity futures returns, *i.e.*, how one commodity futures return depends on the others. The copula framework offers a great deal of flexibility for modeling multivariate distributions, as marginal distributions can be characterized separately from the dependence structure (copula) that links them and forms a joint distribution. Thus, copula-based models can capture rich patterns of tail dependence or extreme price co-movement (see *e.g.*, Oh and Patton, 2018; Fei *et al.*, 2017). The generalized autoregressive score (GAS) Factor copula model, in particular, is very feasible for modeling high-dimensional dependence because by setting a latent variable driven by common and idiosyncratic factors, it notably reduces the number of variables.

Main Results

The main data are weekly futures *excess return* indices of eleven major commodities, including corn, wheat, soybean, West Texas Intermediate (WTI) oil, Brent oil, natural gas, gold, silver, copper, aluminum, and sugar from the Bloomberg Commodity (BCOM) Index Family. The exact methodology for calculating each of the eleven excess return series is in Bloomberg (2021), but briefly, "[t]o avoid the delivery process and maintain a long futures position, nearby contracts must be sold and contracts that have not yet reached the delivery period must be purchased. This process is known as 'rolling' a futures position." Each of the study's eleven BCOM indices are "rolling indices" in that they simulate the return impact of successively going long and rolling individual commodity futures contracts over the duration of the study's time horizon.

The sample period is from January 1991 to June 2019 as dictated by the availability of IP growth data for a broad panel of 35 countries from the Trading Economics Database.

The authors identify the extreme price co-movement by aggregating multiple price sets of commodity futures. The scales of extreme price co-movement can be defined in two dimensions. On the one hand, a parameter *k* represents how many commodities futures are expected to move together. On the other hand, upside or downside co-movement is estimated separately based on returns over a yearly horizon lying above or below some specific thresholds. For example, the baseline investigation starts by setting *k* = 7, then *SU*_90% denotes the expected probability that 7 out of 11 commodity futures returns will go beyond their 90th percentile while *SD*_10% denotes the expected probability that 7 out of 11 commodity future returns will go below their 10th percentile.

The probability of observing a large return fall (*SD*_10%) is significantly higher than the probability of observing a large return increase (*SU*_90%). On the other hand, since 2000, both *SD*_10% and *SU*_90% experience more significant peaks and troughs, and their volatilities both significantly increase, with *p*-values of 0.000 for *SU*_90% and 0.008 for *SD*_10%. Moreover, the probability of observing large return increases (*SU*_90%) also increases significantly. In contrast, no significant increase in *SD*_10% is found. This implicitly confirms the relevance of a growing literature concerned with high volatilities and large increases in commodity futures prices over the last two decades (*e.g.*, Cheng and Xiong, 2014).

Using ordinary least squares (OLS) regression analysis, this research paper documents a significant association between the extreme price co-movement of commodity futures and the subsequent IP growth rate. In general, one standard deviation increase in *SU*_90% (*SD*_10%) is associated with an average 0.339% (0.575%) increase (decrease) in IP growth rate over the following quarter. Moreover, the paper finds an asymmetric effect: the negative effect of downside return extremes is of a larger magnitude and more significant than the positive effect of upside return extremes. Notably, this result is obtained by controlling many prevalent uncertainty variables that can affect economic activities, such as the volatility of oil and stock markets and macroeconomic uncertainty; thus it adds a new source of risk for the real economy as compared to previous studies.

The authors carefully examine the robustness of the measures by loosening the degree of synchronized movement and the magnitude of the price changes. Besides, because not every country has the same industrial structure, different countries may have a different reliance on commodities. Thus, from country to country, the IP growth rate could be clustered together with regard to *SU* and *SD* and this violates the independence assumption of the OLS regression. To mitigate this issue, the authors conduct additional regressions using a hierarchical linear model. Across all cases the paper observes a significant concurrent reaction from goods producers; that is, extreme price co-movements do matter to their later production and, specifically, downside uncertainties appear to have a priority in their decision making.

Conclusions

In this paper, the authors measure synchronized downside and upside extreme co-movements of commodity futures returns in diverse markets by estimating copula models with weekly prices of 11 major commodity futures indices. Further, through dynamic regressions, they further investigate their quarter-ahead predictive content using IP growth rate for a broad panel of 35 countries.

Overall, the paper finds that the upside (downside) extreme price co-movement is positively (negatively) associated with IP growth over the following quarter. Furthermore, the relationship is *not* symmetric: the net impact of downside extremes is very robust whereas that of upside extremes is weaker.

These results have implications for recent work on reconciling two seemingly contrary strands of the literature between the standard cost effect and informational effect (Sockin and Xiong, 2015). On the one hand, the paper's analysis provides a coherent illustration that goods producers are more sensitive to downside risks. When faced with a sharp increase in commodity prices, cost concerns appear to offset the expectation of an economic boom led by informational theory. On the other hand, the fear of an economic bust dominates the benefits of cost savings when an extreme negative price co-movement is present.

Endnote

1 Among the literature, most work focuses on the pricing impact of financial investors on individual commodity futures, with little study on the economic impact of the resulting prices.

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Keywords

Extreme price co-movement, commodity futures, industrial production growth, GAS-factor copula, panel regressions.

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The Smile of the Volatility Risk Premia

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The paper presents selected results from the comprehensive study of the volatility risk premium (VRP) in the oil market. We introduce the smile of VRP that represents variation in profitability and risk of this systematic strategy across option moneyness and maturities. We identify the structural break in VRP evolution over time driven by behavioral changes among producer hedgers and the securitization of the strategy by financial institutions.

Introduction

Commodity options resemble insurance contracts. Option buyers pay the premium to protect themselves against the adverse price movement. Producers buy puts to ensure minimum acceptable return on investments in capital intensive projects; consumers buy calls to protect against price appreciation of raw materials essential to their manufacturing process or to the services they provide. Sellers of commodity options are dealers, institutional investors, and professional volatility traders acting as insurers in anticipation of reward for providing the service of risk absorptions.

Like any other insurance product, writing commodity options carries asymmetric risks. Small frequent gains in the form of premium collected create a buffer to offset the impact of rare but potentially large losses. To keep providers motivated to stay in business with such asymmetric payoffs, prices must be set at a premium to the contract actuarial value, or its average historical payout. Despite similarities to the traditional insurance industry, commodity options have one important advantage. In the derivatives market, the asymmetric option risk can be partially offset by dynamically trading the futures contract, the instrument on which the option is written. This technique, which became known as delta-hedging, replaced actuarial pricing of options with the cost of their dynamic replication. Delta-hedging cannot eliminate the asymmetry of the payoff, but it transforms the strategy risk profile. The investment return on such a dynamically hedged short option strategy is known as the volatility risk premium, or VRP.

Volatility Risk Premia by Moneyness and Maturity

In this short paper, we summarize some important observations resulting from the comprehensive study of VRP strategies for West Texas Intermediate (WTI) options. We have constructed the broad set of systematic volatility strategies for options across different moneyness and maturities using daily data since 2000. The moneyness of the option can be thought of as a deductible on the insurance contract, and it should not be surprising that the profitability of option selling varies significantly with the choice of moneyness. We define moneyness simply as the ratio of the strike price to the futures price and analyze strategies for the range of moneyness from 0.9 to 1.1. Our results provide some new insights on the variation of the risk premium across parameters that characterize various options. We find that VRP exhibits the pronounced smile with much higher returns generated by selling out-of-the-money (OTM) options, especially for contracts with shorter maturities.

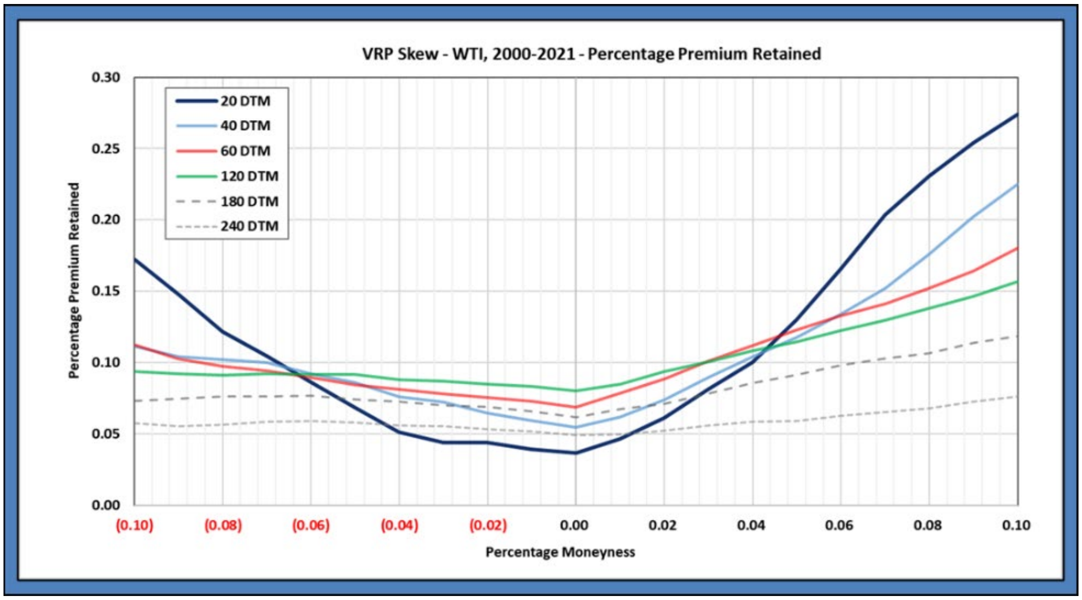
When it comes to option trading, the concept of investment return is ambiguous and needs to be clarified. For linear instruments, such as futures, the return is typically presented as net profit expressed as the percentage of the notional value of futures at the time of investment. In practice, the actual required cash investment to trade futures is significantly smaller and is limited to the initial margin posted with the clearing broker, but such metric would have been difficult to track as it fluctuates with the market volatility. For similar reasons, and to keep the results simple and transparent, we define a normalized profitability metric for VRP strategies as the percentage of the premium collected. Similarly, the concept of investment risk needs to be clarified in the case of options, which we discuss separately below.

In addition to studying the strategy across moneyness, we also construct VRP term-structure. We analyze the volatility strategy for the range of maturities from one month to one year. We first study each position in isolation before considering the portfolio effect of overlapping positions. For example, for the 60 days to maturity tenor, a portfolio of positions would carry three overlapping positions at a point in time. In order to separate the resulting increasing portfolio effect with maturity, we report performance and risk metrics as a function of premium collected on a per-position basis, and then comment on portfolio benefits using more traditional risk-adjusted performance metrics.

To draw an analogy with the way option traders look at implied volatility versus moneyness and maturity, we display VRP performance returns in a similar format. Figure 1 on the next page shows the resulting skew, or the smile, of the VRP. The presence of the smile indicates that the relative profitability of selling out-of-the-money options is higher than selling at-the-money options. The result makes intuitive sense as selling out-of-the-money options carries higher risk and is often compared to picking up pennies in front of a steamroller, whereas selling at-the-the money is merely picking up dimes in front of a steamroller. As a result of higher risk on the wings, sellers are rewarded with retention of a higher proportion of collected premium.

Figure 1 represents terminal profit as a proportion of premium collected. It does not reflect the path-dependent "pain" felt by the investors during the life of the positions comprising the portfolio. Analogous to the manner in which we represent profit as a proportion of premium collected, we represent risk as the average of the maximum loss experienced during the life of each position divided by the premium collected for each position. Figure 2, which is also on the next page, confirms that in return for the potential to retain a higher proportion of premium collected, the investor can expect to feel a greater degree of pain during the life of the trade as a proportion of premium collected. In other words, there is no free lunch.

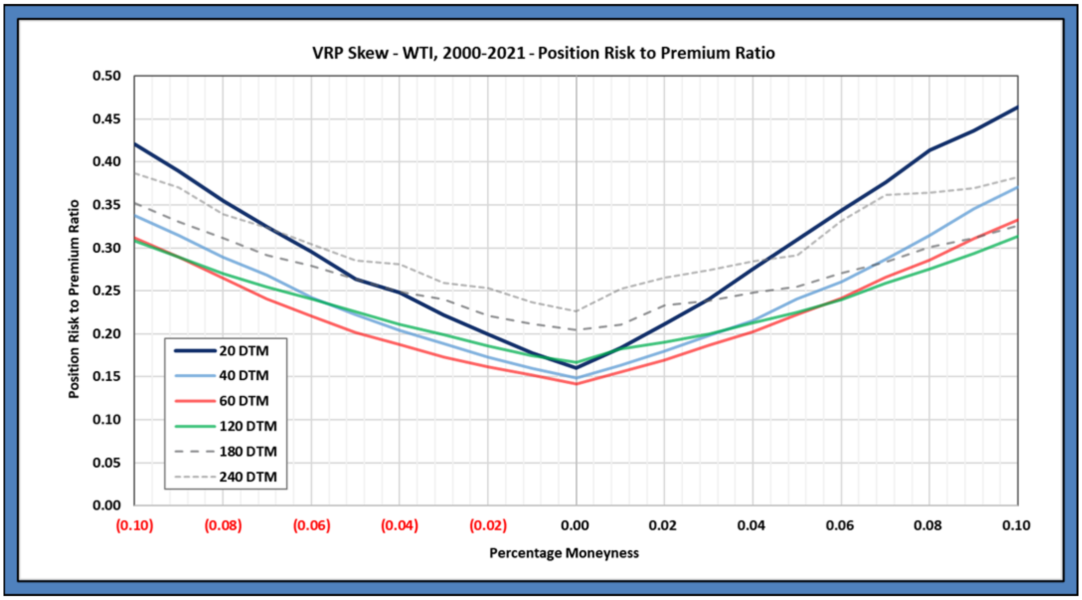
Figure 1



Notes: Percentage of the premium retained in VRP portfolios aggregated by moneyness and maturity.
DTM is an acronym for days-to-maturity.

Sources: Authors' calculation and graphic, CME data.

Figure 2



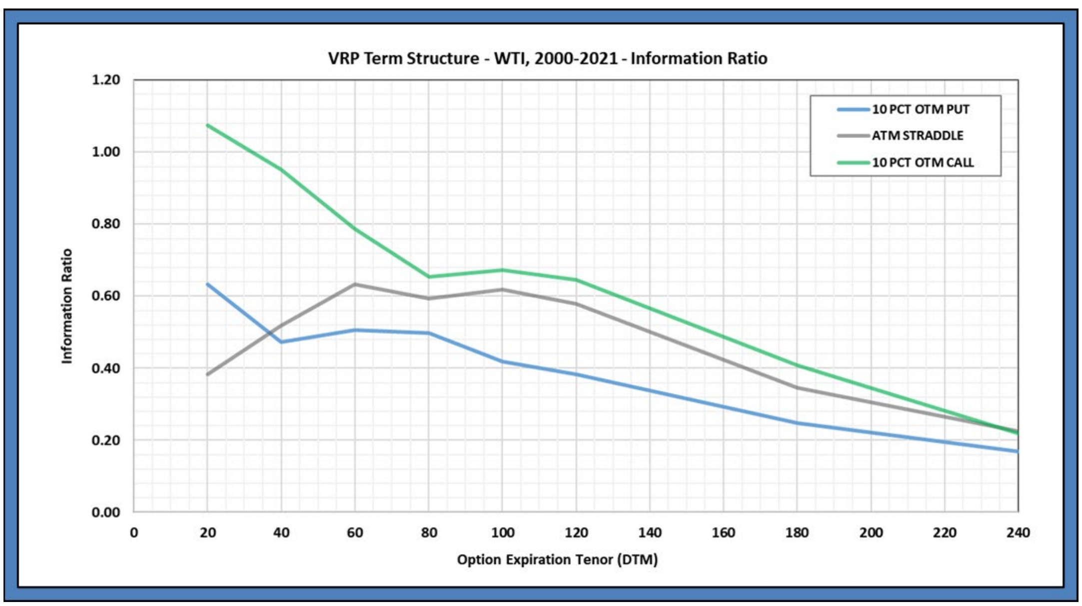
Note: Position risk measured as the average position path maximum loss as a proportion of premium collected by moneyness and maturity.

Sources: Authors' calculation and graphic, CME data.

The intent of the present analysis is to highlight the relative value of VRP across the surface (i.e., across tenor and moneyness) without regard to transaction cost considerations. Efficient implementation of the VRP strategy is a multi-factor topic comprising execution strategies for options entry and futures hedge execution, and use of tactical algorithmic execution for slippage minimization. In fact, the current authors have demonstrated the efficacy of applying machine-learning based algorithmic automated multi-timescale delta hedging to optimize the return on risk characteristics of the VRP capture strategy. Such algorithmic hedging removes human bias and can be tuned to realize risk management objectives while monetizing VRP. The current analysis provides a starting point for identifying candidate portions of the VRP surface that, when combined with tactical execution, provide positive investment returns and decorrelated sources of yield enhancement in certain regimes.

A more familiar approach to characterizing risk for trading portfolios with multiple overlapping positions is to use the so-called information ratio, which we define as the ratio of annualized profits expressed in dollar per barrel to the annualized standard deviation of daily profit and loss. Such definition allows us to avoid the ambiguity of percentage returns for leveraged instruments. Figure 3 shows that for out-of-the-money options the best results are achieved from selling short-term one-month maturity options. In contrast, for at-the-money (ATM) straddles the risk-adjusted performance can be significantly improved if we construct a portfolio of overlapping positions with 60 to 100 days to expiration. Such portfolio benefits are primarily driven by additional strike diversification. Since options that are ATM at initiation are also more likely to be ATM at expiration than options which were initially out-of-the-money, the strike diversification becomes more powerful for ATM straddles as it smooths the portfolio's overall gamma profile.

Figure 3



Notes: The term-structure of Information Ratio vs. Days-to-Maturity (DTM) for a portfolio with multiple overlapping entries. Information ratio is defined as annualized profit divided by the annualized standard deviation of daily price changes.

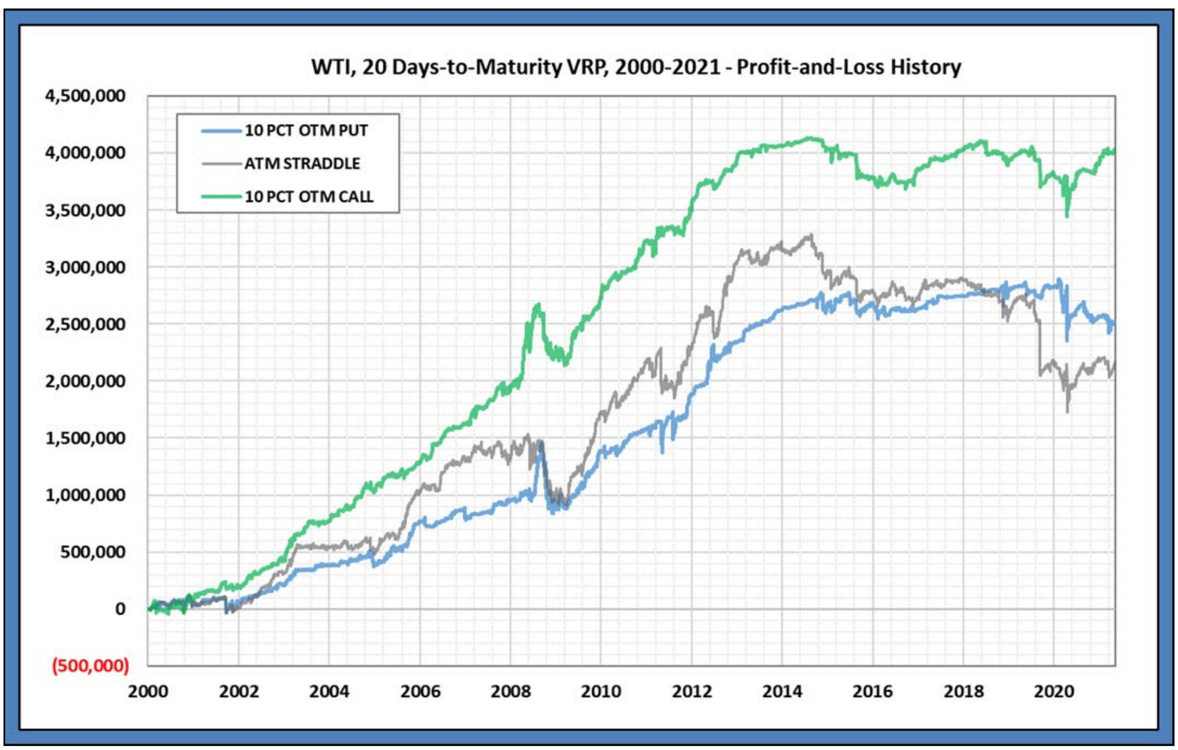
Sources: Authors' calculation and graphic, CME data.

The term-structure of information ratios presented in Figure 3 is provided only to highlight a salient diversification feature of the generic VRP portfolio, and it is not meant to suggest a particular portfolio design. The portfolio construction is a separate topic which we do not address here, but significantly higher information ratios could be achieved with a proper portfolio construction. Importantly, one also needs to be aware of VRP evolution over time which we discuss next.

Hedgers Behavior and Regime Change

Further important insights can be gained by looking at the performance of volatility risk premia strategies over time. Many risk premia strategies in energy markets are known to be sensitive to regimes, as described by Bouchouev and Zuo (2020). Energy markets constantly evolve, adjusting for new fundamental drivers like the growth of shale and structural factors from the market financialization. These factors lead to changing behavior among hedgers and speculators that impact the supply and demand for risk management services, and the resulting volatility risk premium. The VRP strategy is no exception. Figure 4 presents the equity history of the non-overlapping position VRP strategy comprising out-of-the money puts, out-of-the-money calls, and at-the-money straddles, which highlights the presence of a structural break that separates two distinct regimes – three if we consider pre and post financial crisis as two regimes.

Figure 4



Note: Cumulative performance of a non-overlapping position VRP strategy. The strategy sells 100 contracts of 10% out-of-the-money puts, calls and at-the money straddles with one month to expiry and delta hedges daily.

Sources: Authors' calculation and graphic, CME data.

During the decade leading up to the financial crisis, the strategy generated impressive returns with a Sharpe Ratio well above 1.0. For those brave enough to sell into the aftermath, superior returns continued as liquidity providers raised "insurance premiums" and stopped providing liquidity altogether as a result of the carnage felt by the short vol trade. Then by the beginning of 2014 the salad days of the VRP strategy in oil markets were gone. Where did it go and why?

The strategy became a victim of its own success. As the business of passive commodity investments lost its allure pressured by the prevalence of contango and punitive rolling costs, the capital shifted towards more dynamic strategies designed to capture various systematic risk premia. To make it easier for investors, the VRP concept has also been packaged into investable indices, and the cumbersome task of daily delta-hedging was effectively outsourced to index providers. Such indices allowed large pools of capital held by pension funds and other institutional investors to access what used to be an obscure opportunity that previously could only be captured by oil specialists equipped with the right technology and risk management capabilities.

Another important factor behind the structural break in VRP is the evolution of hedging strategies by U.S. shale producers. Unlike traditional oil projects, shale is closer to mining operations where constant drilling is required to keep the production flowing. The shale business has been developed mostly by independent and highly leveraged producers whose access to capital provided by lending banks is often conditional on hedging the price risks. While hedging for producers became nearly mandatory, their ability to pay the premium for the insurance was limited. Instead, their hedging strategies shifted to more leveraged structures, such as costless collars which are net volatility neutral, and three-way collars where producers sell two options, an out-of-the-money put and an out-of-the-money call, to finance the purchase of at-the-money put.

Finally, the impact of one large-scale annual sovereign put buying program consistently executed by the Finance Ministry of Mexico since 2002 gradually became more muted. This program, which is described in more detail by Bouchouev and Fattouh (2020), was designed to protect the country's export revenues, which are heavily dependent on oil, and the program quickly turned into the largest derivatives deal of each year. The hedge effectively treated put options as an insurance product with over one billion dollars spent annually on the option premium. More recently, the hedging volumes were reduced as the country's overall oil production and exports decreased. In addition, to reduce costs in certain years, the strategy of buying outright puts was replaced with buying cheaper put spreads whose overall impact on the volatility is much smaller.

The impressive historical performance of the oil VRP strategy attracted more providers of oil insurance, who were willing to accept lower returns and take on larger risks. In addition, the natural buyers of the insurance, producers and consumers, demonstrated their own creativity by restructuring their approaches to hedging. Instead of buying relatively expensive outright insurance, the hedgers now routinely buy an option and finance it by selling another option, often monetizing the real optionality embedded in their assets.

The business of extracting VRP via the traditional approach of selling at-the-money straddles is no longer attractive for financial investors. However, the aggregate premium has not entirely disappeared, rather it became somewhat spread out across various strikes and maturities, but not in a uniform manner. The opportunities to provide insurance-like products in commodity options became more dynamic with some options becoming more expensive than others. To spot these opportunities, one needs more granular quantitative metrics for the performance of such tailored strategies. Like the concept of implied volatility skew became the standard tool for the volatility traders, we believe that the concept of the volatility risk premium skew could become as valuable for systematic risk premia investors seeking new sources of alpha.

Endnote

For further coverage of the crude oil markets, one can also read past *GCARD* articles on this topic.

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Gold and Bitcoin – A Short Study of Two Carbon Impacts

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In a previous article (Björk Danielsen, 2020), I discussed how investors could think about ESG and commodity futures. I argued that exposure to commodity futures contracts cannot reasonably define a carbon footprint. This is because a long or short position in a commodity futures contract does not create nor destroy any supply of the commodity in question.

However, there are also popular commodity investments where investors prefer to buy the actual commodity "physically" and store it. This has long been the case for investment in gold, and more recently, direct investments in bitcoin and other cryptographic assets. For these investments the carbon impact becomes a tangible and meaningful quantity to understand, as investors directly contribute to demand.

It may be argued that withholding scarce commodities from other uses "lock in" the one-time emissions from producing them. Once the investment is ended, this internalized carbon content can be seen as passed on to the next investor, or consumed by a commercial buyer. In fact, it is unlikely an investor in either gold or bitcoin will be the first owner of that asset.

In this article, I share an approximate analysis of the emissions "internalized" into gold and bitcoin. The calculations are based on the relevant emissions from production without delving into later lifecycle emissions. The goal is to give investors useful "rules of thumb" for understanding the orders of magnitude at play. I also want the reader to understand the underlying assumptions and calculations, so that they are able to recreate the results using the cited public sources.

Throughout this article, I will be speaking in the unit that I believe makes the most sense for judging investment carbon impact: metric tons CO2 equivalent per million dollars of capital (tCO2e/M$). I not only want to compare gold and bitcoin emissions but I also want to put them into context using multiple comparisons, including: how do these emissions compare to the currently traded prices of carbon; how do these emission intensities compare to the equivalents of industrial and agricultural commodities; and how do they compare to the emissions from the activities of corporations underlying popular equity indices?

Results Relative to the Price of Carbon

The table on the next page presents the intensities I have arrived at for gold and bitcoin. Additionally, it also introduces a third commodity: the emission allowance. The European Union Allowance (EUA) is the largest market for the price of carbon, based on trading certain European emissions restricted to a common cap by regulation. Emission allowances are also becoming increasingly interesting commodity investments, but here I will only use them as carbon content measures.

From the table below, one can conclude that based on 12-month average prices as per June 2021, the emission intensity of bitcoin is about 12 times that of gold. But perhaps more interestingly, matching the emissions intensity of gold to allowances under the European scheme would only make up 1.5% of the price of the commodity, while emission compensation through the use of EUA's would cost 18% of the price of bitcoin.

Table 1

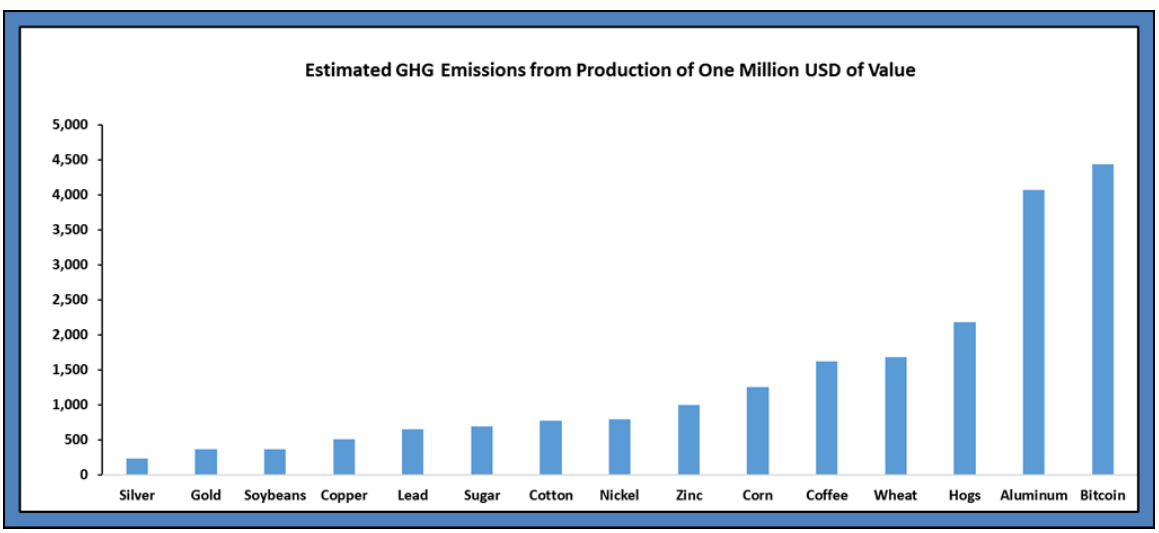
	CO2e internalized	1y avg price Jun 21	Resulting intensity
Gold [1]	21.76 tCO2e/kg	$59,639/kg	364 tCO2e/$M
EUA Carbon Price[2]	-1 tCO2e/allowance	35.5 €/allowance	-23,916 tCO2e/$M
Bitcoin [3]	131 tCO2e/coin	$29,595/coin	4,435 tCO2e/$M

[1] Based on Table 3 of World Gold Council (2019). Upstream and recycling Scope 1 & 2 (direct and indirect) emissions divided by all production.
[2] Assuming the emission rights' nominal allowance quota as its internalized emissions.
[3] See Appendix A for calculation.

Relative to Other Commodities

Physically storing base metals or grains for their value is not unheard of, yet is very uncommon as these commodities are perishable goods with industrial uses. Nevertheless, by expanding my methodology from the previous section to a broader set of commodities, it is possible to place gold and bitcoin in a broader commodity context. Figure 1 shows that on a per dollar basis, precious metals such as gold and silver generally hold lower intensities compared to industrial commodities or even grains and softs. (See Appendix B for calculations.) Simultaneously, only the most emission heavy industrial commodities come close to the emission intensity estimated for producing bitcoin.

Figure 1

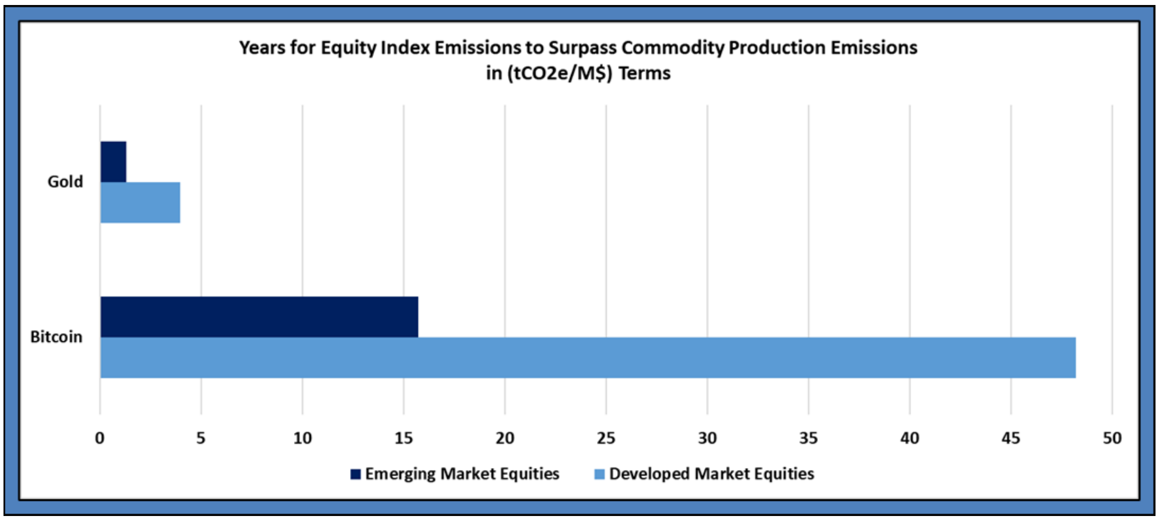


Compared to Equity Indices

The emissions from an equity investment are essentially different from a precious metal investment. Equity investments produce both ongoing annual emissions and annual cashflows. There is no unequivocal way of comparing the two, so I have settled for the simplest: the number of years it takes for the companies underlying a similar size equity investment to emit a similar GHG footprint as the one-time emission that is needed to produce the same value of the compared commodity.

According to a proprietary analysis of APG Asset Management, the capitalization weighted emissions of the MSCI World developed market and emerging market indices were as per June 2021 approximately 93 and 282 tons per million dollars invested. This means that the emissions from producing a million dollars' worth of gold today creates the same carbon footprint as 1-4 years' worth of ongoing emissions attributed to a million dollars invested in equities. By the same calculation, mining bitcoin produces emissions equivalent to a staggering 16 to 48 years' worth of current equity index emissions at the same dollar value. See Figure 2.

Figure 2



Conclusions

Precious metals, and gold in particular, are primarily used for store-of-value purposes. Mining these metals causes considerable initial one-time emissions, which the global gold producing industry would have to cut in the coming years to be in line with national Paris agreement aspirations. The industry has presented ambitious roadmaps towards decarbonization (World Gold Council, 2020). Investors who include gold in their portfolios should track the industry's progress towards these goals over the coming years.

However, studying the current situation, I was able to conclude that the high value of gold causes its total mining emissions per dollar of value to be low compared to that of most industrial commodities. Furthermore, I concluded that the production of investment gold today produces reasonable emissions when compared to the ongoing emissions produced by the constituent companies of popular equity indices.

Meanwhile, the same cannot be said for investments into bitcoin. Today, many cryptographic assets, and bitcoin in particular, are extremely carbon intensive in nature. To make matters worse, unlike precious metals, the emissions of bitcoin are not limited to its primary mining emissions – simply transacting these assets in the future will produce considerable further emissions. The number calculated in this study are indicative and likely to change, given that the bitcoin network's emissions fluctuate as the hash rate and the sources of energy used to create it will be variable due to changes in profitability and regulation. Nevertheless, bitcoin will remain energy intensive in the future, as the miners' cost base will remain tied to power.

Bitcoin's decentralized nature also makes it much harder to "green" compared to traditional mining: it cannot be efficiently regulated with carbon border taxes or local cap-and-trade schemes that are likely to affect the gold industry in the coming years. Individual investors can today choose to buy bitcoin generated with fossil-free energy sources. However, such purchases are likely to support the price of bitcoin, which in turn is likely to not only increase mining activity, but also increase the emission intensity of that activity more directly than in the case of traditional mining.

I therefore conclude that for a more sustainable future, cryptographic assets will have to undergo technological changes. Most centrally, modified coins or tokens that are not reliant on the proof-of-work based consensus mechanisms described in Appendix A will have to become commonplace. Currently, it is hard to make the case that bitcoin can reasonably be part of a sustainable investment portfolio.

Appendix A
Bitcoin Emission Intensity Calculation

Bitcoin's decentralized transaction validation protocol is based on a Proof of Work (PoW) consensus mechanism for validating blocks of transactions. Validators, or "miners," essentially compete in solving an arbitrary computational problem based on reverse-engineering cryptographic hashes (Keenan *et al*., 2018). The miners are awarded for validated blocks in bitcoin. This "mining" is done today primarily using specialized computer hardware, and the total computations done by miners is described by the bitcoin network hash rate.

Because bitcoin is not centralized, there is no exact central registry of the identity of miners or the hardware and power source they use to produce these hashes. What can be deduced about its public ledger is the current hash rate and the approximate geographical distribution of the hardware producing it. Power use and carbon intensity of that power must then be separately estimated.

Various studies have estimated power usage under different assumptions. Some studies have performed a bottom-up analysis, studying the efficacy of the likely mining hardware portfolio in use. Meanwhile, others have turned the problem around, calculating total mining revenue assuming the power share fixed. The Cambridge Bitcoin Electricity Consumption Index (CBECI) uses the former approach while the

Digiconomist's Bitcoin Energy Consumption Index (BECI) the latter. Both of these indices are available publicly on the internet on a daily basis. Both indices are quite volatile, as changes in the price of bitcoin will immediately trigger a response in the form of additional mining hardware being deployed or removed from the network. Recent values of both indices are seen in Table A1 below. Because both of these methods have their particular advantages and drawbacks, I have used the average of the latest CBECI and BECI numbers as my best point estimate.

Table A1

	As of 1 Jun 2021	1 year average
CBECI	70 TWh	51 TWh
BECI	105 TWh	85 TWh
Average	88 TWh	68 TWh

For estimating the carbon intensity of this power, multiple estimates also exist. At the time of analysis, the current best estimate remains that of Stoll *et al*. (2019), setting intensity at 480-500 kilograms of CO2 equivalent per megawatt hour of power (kgCO2eq/MWh). I will use the midpoint of 490 kgCO2e/MWh for this analysis. This is a fairly high intensity, reflecting the currently large share of mining taking place in China's predominately coal-powered grid. We can contrast the intensity of the power used by bitcoin miners with the 2019 U.S. and E.U. grid averages of 408 kgCO2e/MWh and 255 kgCO2e/MWh respectively (EIA, 2020; EEA, 2021).

The final piece of the puzzle is the output of mined bitcoin. This comes by construction from the bitcoin algorithm releasing one block approximately every 10 minutes, implying (365*60*24)/10= 52,560 blocks per year. Miners of a particular block are rewarded by a block reward, which is also by construction halved roughly every 4 years. As of 2021, the block reward stands at 6.25 bitcoins (BTC). This translates to 6.25*52,560 = 328,500 bitcoins as being produced per year. Attributing the full emissions of the hash rate to the production of bitcoins thus gives us (490,000 tCO2e/TWh * 88 TWh)/328,500 BTC = 131 t/BTC or 4,435t/$M, when using the current 12-month trailing average price of bitcoin ($29,595). (TWh stands for terawatts of power.) Looking at the many approximate values plugged into this calculation, it is clear that this estimate is a very rough estimate. All of the inputs used are likely to change a lot in the coming years based on the economics of mining and attempts to regulate the market.

It is also essential to note that this estimate does not include the additional energy or broader ecological footprint attributable to the production of the specialized chips often used for the sole purpose of bitcoin mining.

Appendix B

Approximate Emissions from Producing Selected Commodities

Comparing emissions of different commodities on equal footing is challenging. The table on the next page summarizes various estimates of directly caused emissions. Different sourced studies use slightly differing assumptions and methodologies in their analysis. These estimates are also based on data samples from different geographical locations and time periods. Because of these differences, the numbers in the table below should only be seen as an effort to form indicative and somewhat comparable measures of CO2 equivalent emissions. I have attempted to include Scope 1 and 2 emissions measures that are available from publicly available sources, excluding LULUCF (Land Use, Land-Use Change, and Forestry) offsets, and based on a global warming potential (GWP) of 100 years. I have chosen not to deduct any figures for carbon sequestered into the commodity itself, nor any downstream emissions such as emissions or sequestrations caused when consuming the commodity. These numbers should reflect both energy-related and other direct emissions caused by the work of mining, growing or refining the commodity in question. For agricultural products, I base my analyses on regional U.S. supply in order to match the price benchmarks used in the intensity calculation. For the intensity's price denominator, I use 12-month average prices of the most liquid futures contract. The 12-month average was applied in order to smoothen results and to control for effects of commodity price seasonality.

Table B1

	GWP 100 CO2e emissions (ton per ton)	12-month average price per ton from futures	Emission intensity tCO2e/$M	Source of life-cycle analysis
Silver	196	$820,809	239	Nuss and Eckelman (2014)
Soybeans	0.17	$483	366	Field to Market (2016)
Copper	4.08	$7,940	514	International Copper Association (2017)
Lead	1.3	$1,987	654	Davidson *et al.* (2016)
Sugar	0.23	$331	696	Seabra *et al.* (2011)
Cotton	1.3	$1,676	776	Field to Market (2016)
Nickel	13	$16,267	799	Nickel Institute and Sphera (2020)
Zinc	2.66	$2,662	999	International Zinc Association (2016)
Corn	0.22	$176	1,250	Field to Market (2016)
Coffee	4.51	$2,778	1,624	Giraldi-Díaz *et al.* (2018)
Wheat	0.38	$226	1,682	O'Donnell (2008)
Hogs	3.9	$1,742	2,183	Thoma *et al.* (2011)
Aluminum	8.27	$2,033	4,068	Aluminum Association (2013)

Abbreviations: GWP stands for Global Warming Potential, and tCO2e/$M stands for metric tons CO2 equivalent per million dollars of capital.

Endnotes

The views and analyses in this article may not reflect those of the author's employer. In addition, the author would like to thank Alex de Vries, the founder of Digiconomist.net, for good discussions on the future outlook for bitcoin emissions.

For further coverage of cryptoassets, one can also read past *GCARD* articles, as well as a transcription of a JPMCC industry panel, on this topic.

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Volatility, Contango, and Crude Oil Inventories: A Complex Relationship
The Changing Nature of World Oil Markets

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The general theory of storage suggests that the level of inventories is a key factor in determining the basis over time. The basis is the difference between the price of oil in the futures market and the price of oil in the spot market. As an indicator of future price movements, the basis follows a different dynamic when inventories are in scarce supply or in surplus, implying that there are different market states that reflect different underlying crude oil market conditions. We apply a Markov regime switching model to analyze this complex relationship, using a spread option value of storage metric to represent market structure, which enables us to draw preliminary conclusions on how to potentially impact oil-market-price stability via precise inventory decisions.

Introduction: Exploring the Relationship Between Inventories and Market Structure in the Oil Market

Given the volatile nature of global oil markets and their sensitivity to geopolitical and economic shocks, at any given time there may be a "well balanced" oil market, or surpluses or shortages of crude oil supplies. In this dynamic environment, even the suggestion of changes to crude oil demand, supply, or inventories can trigger a price reaction and a subsequent rebalancing of world oil markets.

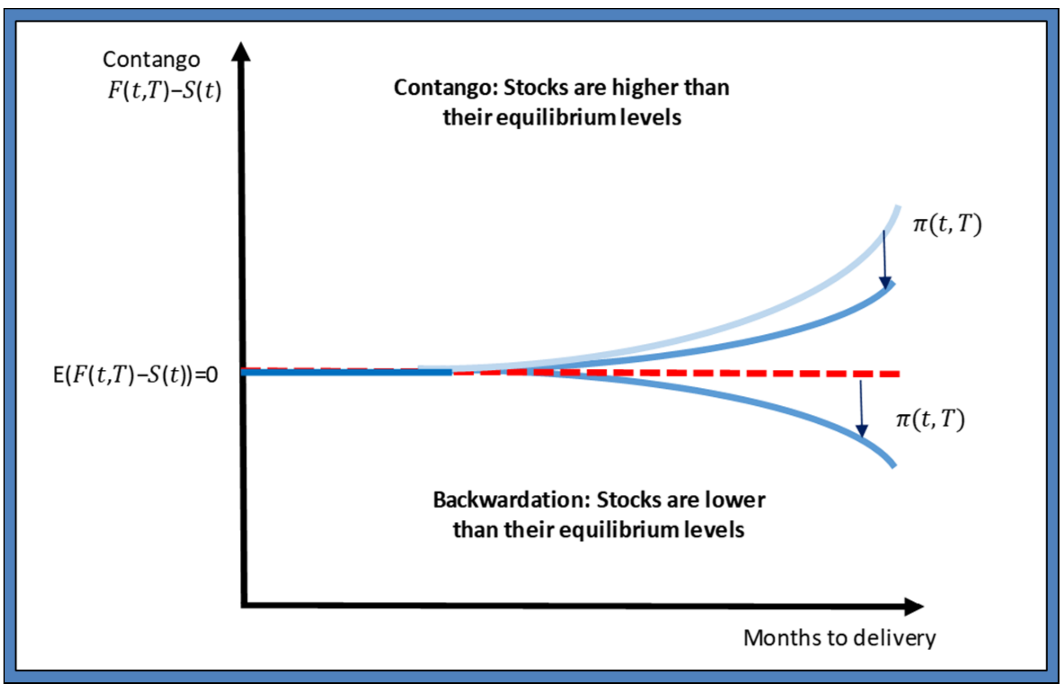
Under normal market conditions, when the crude oil market is balanced, prices are generally in a state of contango. The price that futures trade above the spot price accounts for the costs of storing a commodity, including warehousing costs, the costs of foregone interest, and a convenience yield on inventories (Fama and French, 1987). When this is not the case, and futures prices trade below the spot price, the market is said to be in backwardation. Firms hold minimal or just-in-time inventories, and they tend to increase production to meet demand (Working, 1933; Brennan, 1958; Telser, 1958).

Conventional storage theory predicts a positive relationship between inventories and the basis (defined here as the difference between the futures price and the spot price) or cost of carry, or a negative relationship between the marginal convenience yield and inventories. The relationship is dynamic and changes according to the conditions in world oil markets. The convenience yield falls with inventory levels but at a decreasing rate. When stocks are scarce, the marginal convenience yield will likely be higher than the convenience yield, and the basis will be negative (backwardation). As the level of inventories rises, the convenience yield falls to levels below the cost of carry, and the basis becomes positive (contango) (Fattouh, 2009; Pindyck, 2004).

An alternative theory suggests that the basis can be explained in terms of a risk premium and a forecast of future oil prices (Bailey and Chan, 1993). The risk premium, π(t,T), reflects all of the systematic factors affecting futures prices, including demand and supply shocks, political risk, and net hedging pressure (Hicks, 1939).

Figure 1 illustrates the risk premium theory of storage. When the difference between the futures price and the spot price, F(t,T) - S(t), is higher than the best industry forecasts of the forward price, E(F(t,T)-S(t)), plus a measure of compensation for the risk of holding a barrel of crude oil or a futures contract, π(t,T), then it will pay to buy a barrel of crude (on the physical or futures market) and sell it forward, and stocks will be above their equilibrium levels. The purchase of spot oil and the sale of futures will reduce the level of contango, F(t,T) - S(t), until the market returns to equilibrium (Bailey and Chan, 1993; Fama and French, 1987). Backwardation is explained by the fact that a buyer of futures contracts will earn a positive risk premium when futures prices are trading below the spot price.

Figure 1
The Risk Premium Theory of Storage



Source: Considine *et al.* (2020b).

The theory can be extended to include the implications of hedging against commodity price risk and storage costs. Hedging against the costs of crude oil promotes upward price bias in a futures market, while hedging against rising storage costs promotes downward price bias in a futures market (Hirshleifer, 1989).

Larson (1994) suggests a nonlinear formulation of the theory, positing that the basis or shadow price of inventories is convex in inventories: "Just as the price of a call option contains a premium based on price variability, so the shadow price of inventories contains a dispersion premium associated with the unplanned component of inventories. When inventory levels are low, the value of the premium increases to the point where inventories will be held even in the face of a fully anticipated fall in price."

Conventional storage theory has been criticized for being a product of pure econometric analysis, rather than traditional economic theory and competitive optimization models. An alternative rational expectations approach models the convenience yield as an embedded timing option. An economic agent that has a long position in crude oil can decide to store the commodity, in which case it will be priced as an ordinary asset, and the forward price will reflect the total cost of storage. Alternatively, the agent can decide to consume it or sell it in the spot market. In this case, the commodity is priced as a consumption good, and the forward price will reflect the convenience yield (Routledge *et al.*, 2000; Deaton and Laroque, 1992).

Several studies have shown that an options-based approach to storage valuation models is superior to the traditional cost of carry and convenience yield models (Omura and West 2015). These studies model the convenience yield as a financial call option that has value in market settings subject to supply shocks (Milonas and Thomadakis, 1997; Heinkel *et al.*, 1990). The positive value of the option, which increases with volatility, can provide an explanation for backwardation in futures contract prices (Heaney, 2002; Sorensen, 2002).

Most of these studies are based on a calendar-style spread option. Considine *et al.* (2020b) proposes an alternative: a spread option-based formulation that adds a locational dimension to the theory and is based on the prices of crude oil at different locations, factoring in costs of storage and transportation, and the time required to transport oil between them. The uniqueness of the locational spread option approach is that one can thereby measure the added value to "long distance" crude oil producers and marketers, who are in competition with other crude suppliers, of being able to sell spot crude from a storage facility near to a main market (Considine *et al.*, 2020a.) This alternative formulation appears to improve the accuracy and precision of models that define the quantitative relationship between market structure and inventories (Considine *et al.*, 2020b).

Each of these formulations suggests that the level of inventories is a key factor in determining the basis over time. The shadow price of inventories, or the basis, is expected to follow a different dynamic when inventories are in scarce supply, suggesting a number of different "price regimes" reflecting different underlying conditions in crude oil markets. Fattouh (2009) investigates this assertion and finds two distinct market regimes. One is characterized by low price volatility when the market is in contango, and an alternative regime is characterized by high volatility when the market is in backwardation. The approach adopts Markov switching modeling, which can be extended to include seasonality and jumps in the pricing process for futures with different maturities (Leonhardt *et al.*, 2017).

In a more recent study, Koy (2017) uses a Markov switching autoregressive model to investigate the recession and growth periods of oil futures markets. The study finds that oil futures prices follow a nonlinear pattern that can be divided into three distinct return regimes.

While past studies suggest that there is, in fact, a well-defined quantitative relationship between the level of inventories and the basis, the exact nature of this relationship is unclear and would appear to change at different times, depending on the market structure at the time of the forecast. This study aims to address the following questions:

- What are the characteristics that determine which market state we are in? Is there more than one market state, or regime, governing potential changes in crude oil inventories? Is there a stable path between different market states?
- How high or low must crude oil inventories be before the markets can be deemed stable?

To answer these questions, we examine the dynamic relationship between the market structure and inventories, using the locational spread option approach. The market structure is modeled as a Markov regime switching (MRS) process, which allows us to identify the number of regimes that govern the dynamics of world oil inventories. We also test whether the level of crude oil stocks has any implications for the probability of world oil markets being in, and remaining in, one of three distinct market-structure regimes.

Methodology and Data

<u>Data and Sources</u>

This section describes the data used in the analysis, and the construction of key variables, including a simple measure of contango, inventories and the locational spread option values. We estimate these variables daily for Rotterdam, and for competing crudes delivered to eight major international storage hubs located at major seaports. They include Fujairah in the United Arab Emirates, Jamnagar (India), Kagoshima (Japan), Louisiana Offshore Oil Port (LOOP in the United States), Ningbo (China), Saldanha Bay (South Africa), Singapore Port (Singapore) and Ulsan (South Korea). For LOOP, where the daily storage rates are available, we add the monthly storage rate on a particular day to the delivery costs.

The daily nine- and two-month futures values for the Brent benchmark, which were sourced from the Bloomberg Terminal, were used for the contango variable.

The daily inventory data is based on the daily floating tank top storage volumes in Rotterdam from September 18, 2013 to January 25, 2019; this data was provided by Orbital Insight. The Savitzky-Golay filter was used to smooth the noise introduced by the satellite data gathering procedure and maximize the signal-to-noise ratio (Press *et al.*, 1996). We will refer to the resulting time series as the Savitzky-Golay smoothed inventories (Inv). (This time series is illustrated in Figure 2 on the next page.)

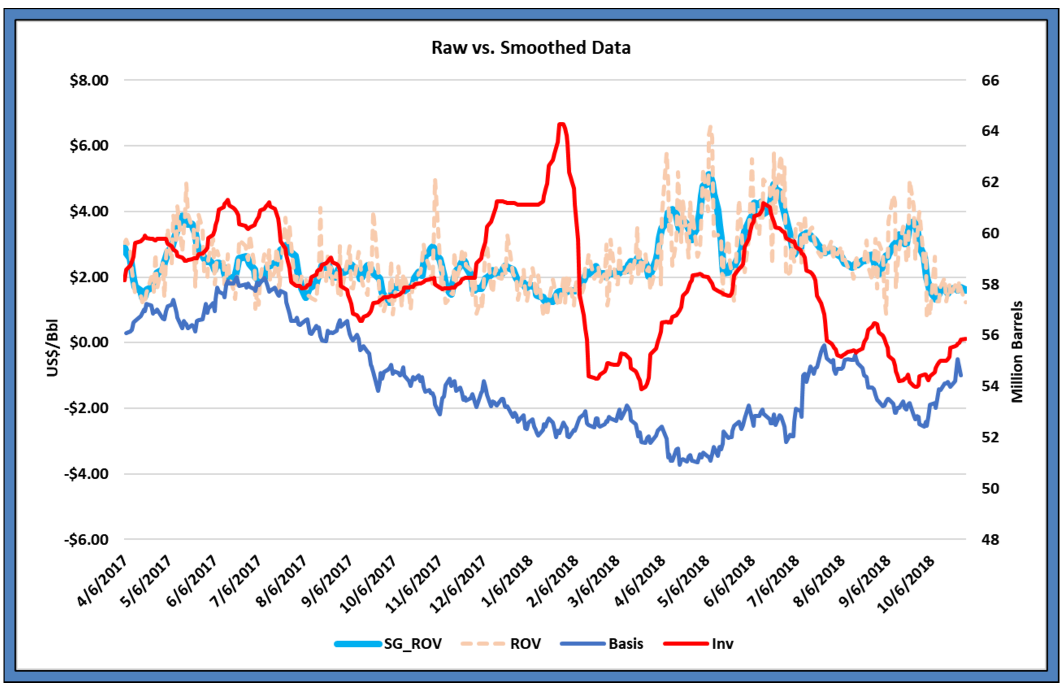
The spread option value (ROV) was obtained from KAPSARC and reported daily for Rotterdam, according to the methodology outlined in Considine *et al.* (2020a) and Considine *et al.* (2020b). Once again, the Savitzky-Golay filter was used to smooth these data and maximize the signal-to-noise ratio (Press *et al.*, 1996). (This time series, SG_ROV, is also shown in Figure 2.)

The spot prices for all the crudes used in the analysis were taken from the Bloomberg Terminal and the shipping costs from Clarksons Research. We applied various national central banks' interest rates, effective on a particular day of the estimation period from December 21, 2015 to January 25, 2019, as a proxy for the cost of capital. These rates were taken from the websites of relevant national central banks and from Triami Media BV. For the Netherlands, we used a one-year zero-coupon bond rate, and for Japan, we used the Japanese yen Libor rate. Both of these datasets were taken from the Bloomberg. The expiry date chosen for the spread options was one month from the date of valuation.

The shipping costs were calculated using the weekly spot freight rates taken from Clarksons Research for crude oil tankers on matching or similar routes. The resulting weekly shipping costs in dollars per barrel ($/b) were interpolated to obtain daily values using a cubic spline multiplicative procedure from EViews. For the cost of carry calculations, we used the same proxies of capital cost to estimate the convenience yield.

This analysis' time series from April 6, 2017 to November 29, 2018 for inventories, the basis, and spread option values are illustrated in Figure 2, which includes both raw and smoothed datasets.

Figure 2
Inventories, the Basis, and Spread Options Values



Sources: Orbital Insights, Bloomberg, and KAPSARC calculations.

A detailed explanation of the smoothing filters, as well as summary statistics and the unit root tests for the variables used in this study, is covered in Considine and Aldayel (2020).

Methodology

To determine the relationship between the market structure and inventories, we postulate the following regression equation of the market structure, as measured by the spread option value (the dependent variable) on inventories and seasonal dummies, using daily data from March 10, 2014 to November 30, 2018.

The regression equation follows the work done by Omura and West (2015), Kucher and Kurov (2014), Fattouh (2009), and Considine *et al.* (2020b), and is represented as:

$$MS_t = \alpha_o + \beta_1 \Delta Inv_t + \sum_i^N \left(\gamma_{i_t} * D_{i_t}\right) + \varepsilon_t \tag{1}$$

where:
$MS_t \equiv$ Market structure as defined by the spread option value,
$\Delta Inv_t \equiv$ Rotterdam inventories as reported by Orbital Insight,
$D_{i_t} \equiv$ A vector of dummy variables, including monthly seasonal dummy variables and a dummy variable for 2014 to 2015, to accommodate the evolution of the data collection process from Orbital Insights, and
$\alpha_o, \beta_1, \gamma_{i_t} \equiv$ Estimated parameters.

The regression was estimated for the different market states or regimes using the Markov regime switching model. Markov switching models are used to describe situations where the behavior of the variables, or stochastic processes, change from one regime to another. The model captures the behavior of a "state variable" that cannot be directly observed (s_t), such as a recession or depression in gross domestic product (GDP) growth. For the oil industry, the state variables that cannot be observed are a state of excess supply (an oversupplied market), excess demand (an undersupplied market), or balanced world oil markets.

$$p(MS_t|Inv_t; D_t; s_t) = \begin{cases} p(MS_t|Inv_t; D_t; \theta_1)\ if\ s_t = 1 \\ p(MS_t|Inv_t; D_t; \theta_2)\ if\ s_t = 2 \\ p(MS_t|Inv_t; D_t; \theta_3)\ if\ s_t = 3 \end{cases} \tag{2}$$

where:
$\theta_m = \alpha_{om}, \beta_{1m}, \gamma_{i_m} \equiv$ Estimated parameters associated with regime m, with three distinct regimes (1, 2 and 3). The state variable evolves according to a Markov chain process. That is, the probability of being in any particular regime, or state of the oil market, in period t depends only on the state of the oil market in time (t-1) and not any other time (t-2) or (t-3).

The Markov chain process for the oil market has the following transition probabilities:

$$
\begin{aligned}
P(\lfloor s_t = 1\rfloor | s_{t-1} = 1) &= p_{11} \\
P(\lfloor s_t = 1\rfloor | s_{t-1} = 2) &= p_{12} \\
P(\lfloor s_t = 1\rfloor | s_{t-1} = 3) &= p_{13} \\
P(\lfloor s_t = 2\rfloor | s_{t-1} = 1) &= p_{21} \\
P(\lfloor s_t = 2\rfloor | s_{t-1} = 2) &= p_{22} \\
P(\lfloor s_t = 2\rfloor | s_{t-1} = 3) &= p_{23} \\
P(\lfloor s_t = 3\rfloor | s_{t-1} = 1) &= p_{31} \\
P(\lfloor s_t = 3\rfloor | s_{t-1} = 2) &= p_{32} \\
P(\lfloor s_t = 3\rfloor | s_{t-1} = 3) &= p_{33}
\end{aligned} \tag{3}
$$

where p_{ii} is the probability of remaining in state i, given that the world oil market was in state i in the last period, and p_{ij} is the transition probability of the markets changing to state i, given that the world oil market was in state j in the last period.

While some representations assume that the transition probabilities are fixed, this would appear to be an overly restrictive assumption for the energy markets. We permit the transition probabilities to vary through time (Bazzi *et al*., 2017; Diebold and Inoue, 1999; Filardo, 1994; Fattouh, 2009).

In this formulation, the probability of switching from one regime to another is a function of the level of contango in world oil markets. The level of contango (c_{t-1}) for Brent crude oil prices is a conditioning vector that contains vital economic information affecting the transition probabilities.

$$P(\lfloor s_t = i\rfloor | s_{t-1} = j) = p_{ij(c_{t-1})} \text{ for i = 1,2,3, and j = 1,2,3.} \tag{4}$$

The estimated parameters for the MRS structure in equation (4) are estimated jointly using a Markov switching regression, a nonlinear optimization technique that uses the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm and Marquardt steps to provide a solution that estimates all the parameters of the complex nonlinear system simultaneously. The BFGS method belongs to quasi-Newton methods, a class of hill-climbing optimization techniques that seek a stationary point of a (preferably twice continuously differentiable) function (Bergmeir *et al*., 2012; Bekiros and Paccagnini, 2015).

Results and Discussion

Three Market Regimes

The results of the MRS analysis using equation (1) are provided in Tables 1 through 3 on the following pages. The model finds clear evidence of three distinct regimes, regime 1—contango, regime 2—backwardation, and regime 3—extreme backwardation.

1. In **regime 1, contango**, the average value of contango is \$2.98, and there is a 90% probability of the values ranging between \$0.43 and \$5.66. The standard deviation of the time series for the contango regime is \$1.69.

2. In **regime 2, backwardation**, the modal value of backwardation is -$2.43, and the standard deviation estimated for regime 2 is $0.41. This regime is the most stable in terms of volatility.
3. In **regime 3, extreme backwardation**, the modal value of backwardation is -$2.67, and there is a 40% probability that the level of backwardation will be lower than -$2.50 $/b. The standard deviation is $8.70, by far the highest of any of the three regimes.

The basis exhibits the greatest volatility when the market is in regime 3, extreme backwardation. This is because backwardation is generally associated with just-in-time inventories, or low and falling stock levels, and can be quite sensitive to shocks, or new developments in the marketplace.

Table 1
Markov Regime Switching Results

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Regime 1				
ΔInv_t	-0.5444	0.2194	-2.4812	0.0131
Regime 2				
ΔInv_t	-2.0745	0.4857	-4.2715	0.0000
Regime 3				
ΔInv_t	1.9793	0.3849	5.1426	0.0000

Source: KAPSARC calculations.

Transition Probabilities

In the MRS analysis, transition probabilities measure the probability of moving from one regime to the next, for example, the probability of moving from contango to backwardation. The mean value of the transition probabilities is given in Table 2 on the next page. These results are similar to those obtained by Fattouh (1999) and show that it is more likely for the basis to remain in contango or to move from extreme backwardation to contango than from contango to extreme backwardation. Unsurprisingly, the market regime was most often in a state of contango during the period under investigation. The expected time duration of backwardation and extreme backwardation is only five and three days, respectively, throughout the observation period.

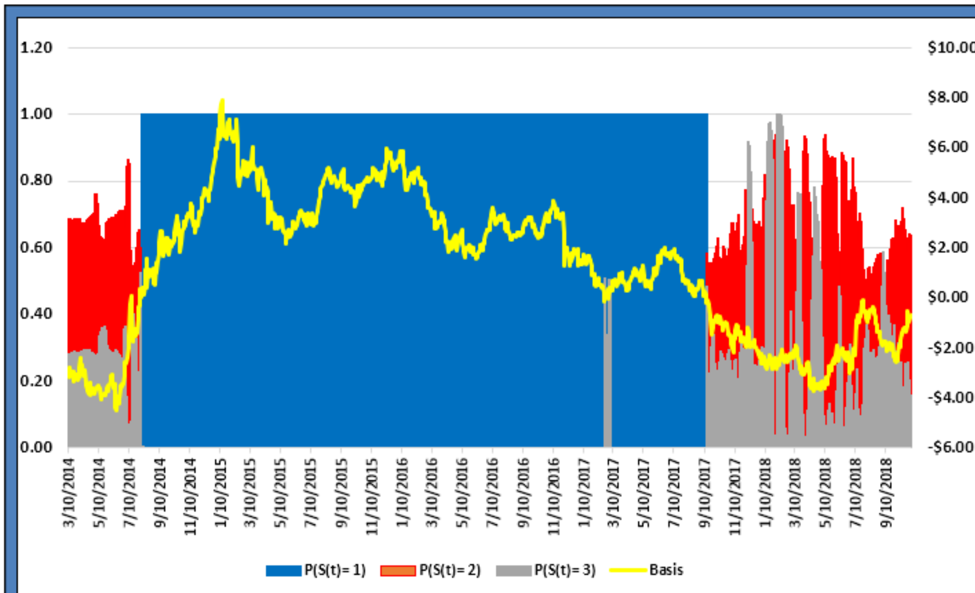
Table 2
Time-Varying Markov Transition Probabilities and Expected Durations

Time-varying transition probabilities:				
P(i, k) = P(s(t) = k | s(t-1) = i)				
(row = i / column = j)				
		1	2	3
Mean	1	0.6681	0.0872	0.2447
	2	0.0479	0.2859	0.6662
	3	0.6681	0.0636	0.2683

Source: KAPSARC calculations.

Figure 3 illustrates the filtered probability of being in regimes 1, 2, and 3, and the level of contango or backwardation in Brent crude oil futures prices. The probability of being in a particular regime ranges from 0 to 1 and is represented on the left vertical axis. The level of contango or backwardation ranges from -$4.5 to $7.9 and is represented on the right vertical axis. The probability of the markets being in regime 1 (contango) is represented in blue, and the probabilities of the markets being in regimes 2 (backwardation) and 3 (extreme backwardation) are given in red and grey, respectively. The level of the basis is given by the yellow line.

Figure 3
Filtered Regime Probabilities



Notes: P(S(t)) is the filtered probability of being in regime t, for t=1,2, and 3.
The filtrations are used to model the information that is available at a given point in time.

Source: KAPSARC calculations

As expected, the MRS estimates of the market structure in the three regimes—as measured by the spread option value—is captured by the actual level of the basis in the marketplace. The probability of the market being in regime 1 almost exactly matches the actual value of the basis. The model captures long periods of contango in the marketplace, and the shifts between backwardation (low volatility) and extreme periods of backwardation (high volatility). The shift back to contango at the end of the sample period, in October 2018, is clearly represented.

The Role of Inventories and Contango

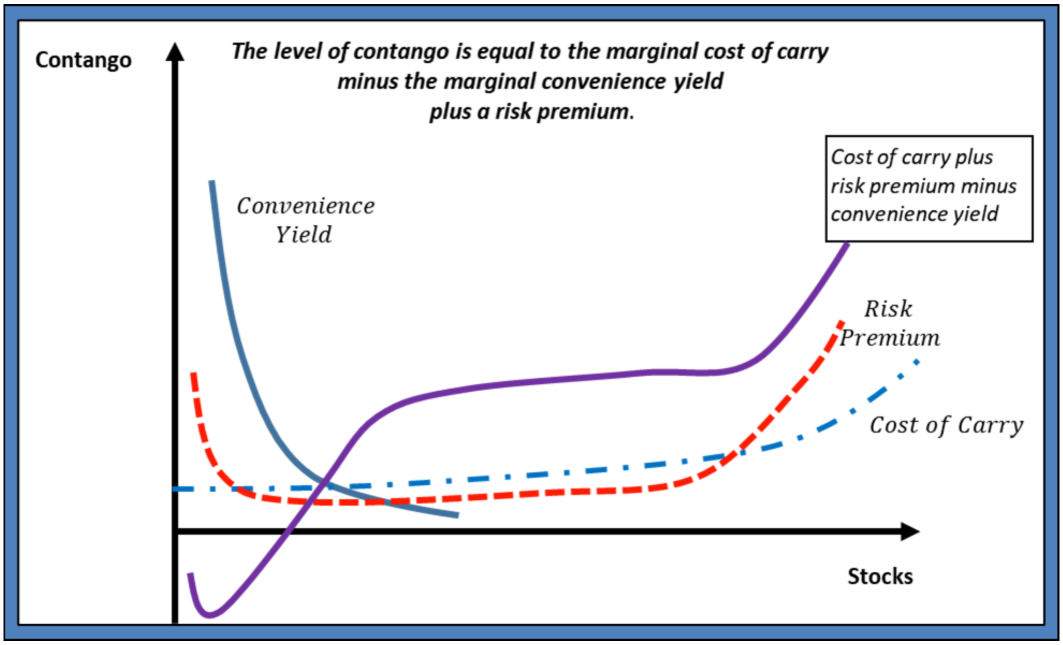
As predicted, the level of inventories varies significantly across the three states. The mean, or average, level of inventories is approximately 61.36 million barrels (MMb) in regime 1, 58.10 MMb in regime 2, and 60.10 MMb in regime 3.

The estimated coefficients of the Markov switching model are all statistically significant at the 1% confidence level. Unsurprisingly, the sensitivity of the market structure—as measured by the changes in the options value—to changes in inventories varies significantly across regimes. The estimated coefficients for the three regimes are as follows: (i) -0.54 for contango; (ii) -2.07 for backwardation, and (iii) 1.98 for extreme backwardation, as was shown in Table 1 above.

Changes in crude oil inventories have a greater impact on the market structure when prices are in backwardation. This is in line with conventional storage theory, which predicts that if stocks are in scarce supply, a reduction in inventories will increase the convenience yield, resulting in a reduction in the futures prices and large movements in the basis.

In extreme periods of backwardation with high volatility, the Markov switching model suggests a positive relationship between the market structure and changes in the level of inventories, and generally heralds a change in the direction of the movement of the basis, from falling to increasing. This can be explained by a slight variation to the risk premium theory of storage, which suggests that the risk premium in times of low storage levels and extremely high levels of volatility will be sufficiently high to induce an increase in the level of the basis when inventories rise (see Figure 4 on the next page).

Figure 4
The General Theory of Storage



Note: Contango = Risk Premium + Cost of Carry – Convenience Yield

Sources: Brennan (1958) and KAPSARC.

Inventories are higher in the contango regime, and there is little incentive to hold more stocks. As such, the convenience yield is lower (or zero), as is the volatility of crude oil prices, which suggests a lower risk premium. In this case, the cost of holding inventories reflects only storage costs and the costs of carry, which are less sensitive to changes in inventories than the convenience yield.

The results suggest that the level of the basis does not have a significant impact on the transition probabilities for most regimes. The sole exception to this general rule is the switch from regime 2 (backwardation) to regime 3 (extreme backwardation). In this case, a change in the direction of the price movement of the basis tends to increase the probability of moving from backwardation to extreme backwardation and high volatility. The estimated coefficient of 0.72 is significant at the 1% level. (See Table 3 on the next page.) This result is consistent with the theory of storage, in that an increase in the volatility of the basis will increase both the risk premium and the option value of storage.

Table 3
Markov Regime Transition Matrix Parameters

Transition Matrix Parameters				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
P11-CONTANGO__BRENT	447.5613	133510.3	0.003352	0.9973
P12-CONTANGO__BRENT	0.490343	0.909485	0.539143	0.5898
P21-CONTANGO__BRENT	-23.42116	57.10263	-0.410159	0.6817
P22-CONTANGO__BRENT	-24.38101	57.10312	-0.426965	0.6694
P31-CONTANGO__BRENT	388.7821	41003.48	0.009482	0.9924
P32-CONTANGO__BRENT	0.720326	0.20128	3.578721	0.0003

Source: KAPSARC calculations.

Finally, we test the proposition that the level of inventories affects the probability of being in each of the individual regimes. To accomplish this, we model the probabilities of remaining in each regime as a logistics function of the level of inventories. The estimated coefficients for the inventory variable in each regime are statistically significant at the 1% level. As expected, an increase in the level of inventories increases the probability of remaining in regime 1, contango. Similarly, a reduction in the level of inventories increases the probability of remaining in backwardation. These results are in line with *a priori* expectations and agree with the general theory of storage. See Table 4.

Table 4
Probability of Being in a Regime versus the Level of Stocks

Regime 1: Contango				
Time Varying Probability of Remining in Regime 1				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-4.0412	1.0890	-3.7108	0.0002
Inventories	0.0520	0.0190	2.7410	0.0062
Regime 2: Backwardation				
Time Varying Probability of Remining in Regime 2				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	4.1415	5.2469	0.7893	0.4301
Inventories	-0.2956	0.0904	-3.2706	0.0011
Regime 3: Extreme Backwardation				
Time Varying Probability of Remining in Regime 3				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.0464	5.0248	0.6063	0.5445
Inventories	-0.2796	0.0867	-3.2240	0.0013

Source: KAPSARC calculations.

Concluding Remarks

Our results show that there are three well-defined and distinct market regimes that govern potential changes in the level of crude oil inventories: contango, backwardation, and extreme backwardation.

Their main characteristics within the time period under investigation are as follows:

1. Contango:
    - Positive basis: The average value of contango is $2.98, the mode is $3.20.
    - There is a 90% probability of the values ranging between $0.43 and $5.66.
    - There is a slight positive skew, but it is fairly evenly distributed. The skewness is 0.2786, so the distribution is fairly symmetrical.
    - Average volatility: The standard deviation of the time series for the contango regime is $1.69.

2. Backwardation:
    - Negative basis: The modal value of backwardation is -$2.43.
    - There is a slight negative skew, but it is fairly evenly distributed. The skewness is -0.2824, so the data has a slight negative skew, but it is fairly symmetrical.
    - Low volatility: The standard deviation estimated for regime 2 is $0.41. This regime is the most stable in terms of volatility.

3. Extreme backwardation:
    - Negative basis: The modal value of backwardation is -$2.67.
    - There is a 40% probability that the level of backwardation will be lower than -$2.50 $/b.
    - Positive skew: The skewness is 0.8853, so the data has a distinct positive skew.
    - High volatility: The standard deviation is $8.70, by far the highest of any of the regimes.

The answer to the question of whether there is a stable path between states is slightly more complex, but it can be derived through a detailed inspection of the transition probabilities. We find that the level of contango does not have a significant impact on the transition probabilities for most regimes. However, when the market is in backwardation, a reversal in the price movement of the basis tends to increase the probability of moving from backwardation to extreme backwardation and high volatility. This, combined with extreme volatility in oil prices and the short duration spent in extreme backwardation, suggests that the transition to the extreme backwardation regime is highly volatile.

The final question of how high or low must inventories be before the markets can be said to be stable, or in a state of contango, can be answered by observing the average level of inventories in each regime. As noted above, the mean, or average, level of inventories is approximately 61.36 MMb in regime 1, 58.10 MMb in regime 2, and 60.10 MMb in regime 3. Using storage data from 2016 to 2018, there is a 69.7% probability of being in the stable contango regime if inventories are above 60 MMb.

The level of inventories does not appear to be as effective as the level of contango in explaining the stability of world oil markets. In regime 1, there is a 40% probability of inventories being below 60 MMb, but only a 5% chance of the level of contango being below $0.43, and a 15.5% chance of the volatility (of inventories) being higher than 1.4 MMb, which is the average level of volatility expected in the unstable, extreme backwardation regime.

Our analysis confirms that there is generally a negative relationship between the spread option value of storage and inventories. In addition, the empirical results suggest that the actual levels of inventories have significant implications for the sensitivity of the market structure to changes in the levels of inventories. Specifically, changes in crude oil inventories have a greater impact on the market structure when prices are in backwardation. When inventories are at sufficiently low levels, and prices are volatile, the risk premium can be higher than the convenience yield, resulting in a positive relationship between inventories and the spread option value (the market structure).

Any policy prescription resulting from this analysis warrants a further investigation of the determination of the risk premium, and the complex relationship between the level of inventories and market structure. Future research could focus on identifying the regimes, the major drivers and their sensitivities for a number of major global crude oil storage and consumption nodes (besides Rotterdam) and alternative crudes (besides Brent). This would help to identify regional differences and create a more comprehensive picture of the global oil market.

The approach developed in this study provides market participants and policymakers with a tool that could be used to track developments in the global oil market and assess a variety of potential future scenarios. Specifically, large producers, exporters and traders can estimate the amount of crude that would have to be stored (delivered) to a particular location to trigger a regime switch in the oil market. For exporters, this can provide an excellent estimate of the additional shipments they can deliver to any location without causing significant pressure on prices. For those interested in balancing the oil market (*e.g.*, the Organization of the Petroleum Exporting Countries), this approach also provides a more precise measure of the additional supply required to bring the markets to a stable, or equilibrium, position.

Endnote

For further coverage of the crude oil markets, one can also read past *GCARD* articles, which include a past paper from a KAPSARC-affiliated author that covered, "The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy."

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Supply-Chain Inflation: Transitory or Durable?

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Introduction

Early-2021 saw synchronous gains for commodity prices, prompting predictions of an imminent commodity super cycle. Price increases both resulted from, and contributed to, supply-chain bottlenecks and broader price inflation in the world economy. This "perfect storm" may prove temporary, and commodity prices themselves have already diverged since mid-year. Nonetheless, asymmetric economic recovery, ongoing COVID-19 risks, and supply dislocations in shipping, manpower and materials persist, sustaining demand for commodities as an inflation hedge for investors. Ultimately, physical dislocations should ease as the world continues to recover from the worst of the pandemic. However, COVID-related issues were compounded by events also illustrating some fragilities inherent in long-haul trade – including extreme weather, transit choke points and cyber-attacks. Simmering geopolitical and trade tensions have also proved disruptive. Looking ahead, while cyclical inflation drivers may ease, policy choices on economic regeneration, the energy transition, and the reshoring of manufacturing could raise supply-chain costs on a more structural basis over the longer term.

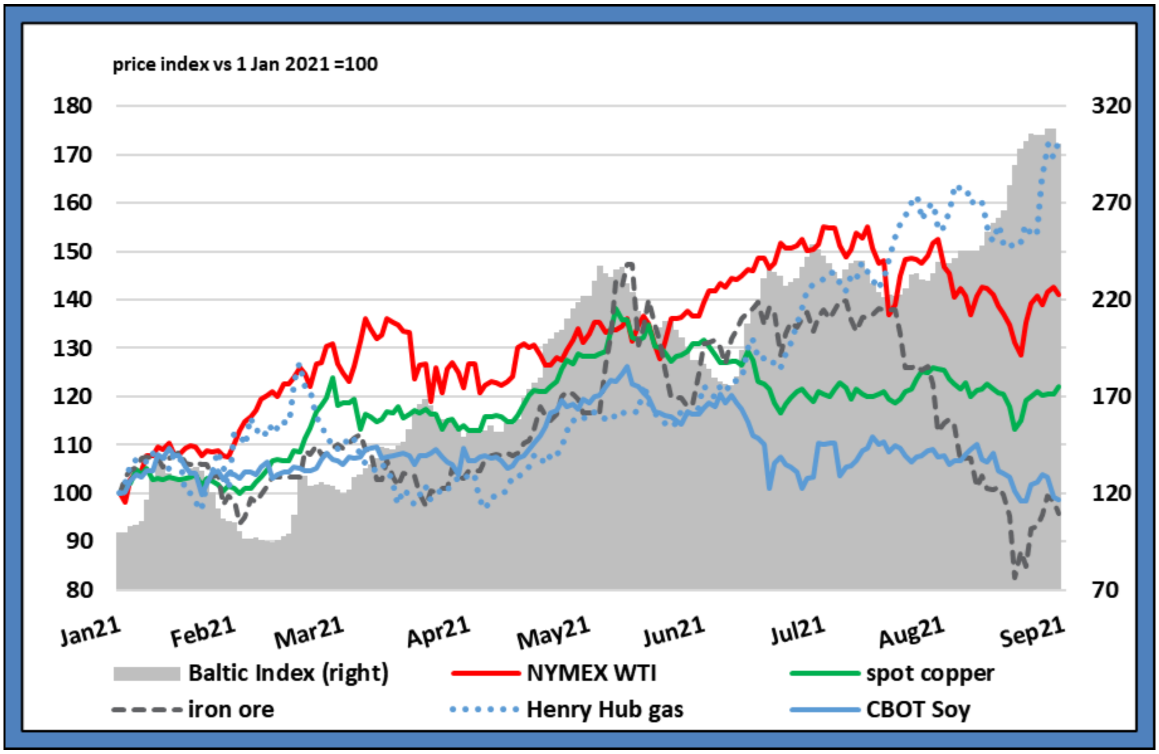
Synchronous Commodity Gains Have Diverged Since Mid-2021

Market optimism for the global economy and commodity markets experienced a sea change around November 2020. This coincided with the U.S. Presidential election (and the anticipation of a proposed new administration spending program) and news of imminent widespread vaccine deployment. Through 1H-2021, robust economic recovery, declining global infection rates, supply-chain disruptions and rising general price inflation coincided with a synchronous strengthening of the commodity complex. Banks and consultancies began predicting an imminent commodity super cycle, overlooking the cyclical distortions inherent in the initial post-crisis recovery, and the disparate state of supply/demand fundamentals prevailing for different commodities, which we also discussed in Fyfe (2021).

Erstwhile strength in iron ore and copper has receded since June as Chinese import demand has fallen. The opposite holds true for coal and natural gas, with bottlenecks caused by the China-Australia trade dispute and supply-chain inflexibilities for liquefied natural gas (LNG) respectively coinciding with strong weather-related demand into Asia.

Crude oil prices also rose strongly through mid-2021 as OPEC+ supply management and recovering demand helped to drain much of the one billion barrels of surplus inventory accumulated in first-half 2020. However, the market has traded sideways since mid-year with one eye on the potential re-emergence of oversupply once again in 2022. Agricultural commodities are also now diverging, with soybeans weakening alongside lower Chinese demand, while coffee and sugar remain buoyed by weather- and COVID-related tightness in Brazilian supplies.

Figure 1
Commodity Prices No Longer a One-Way Bet



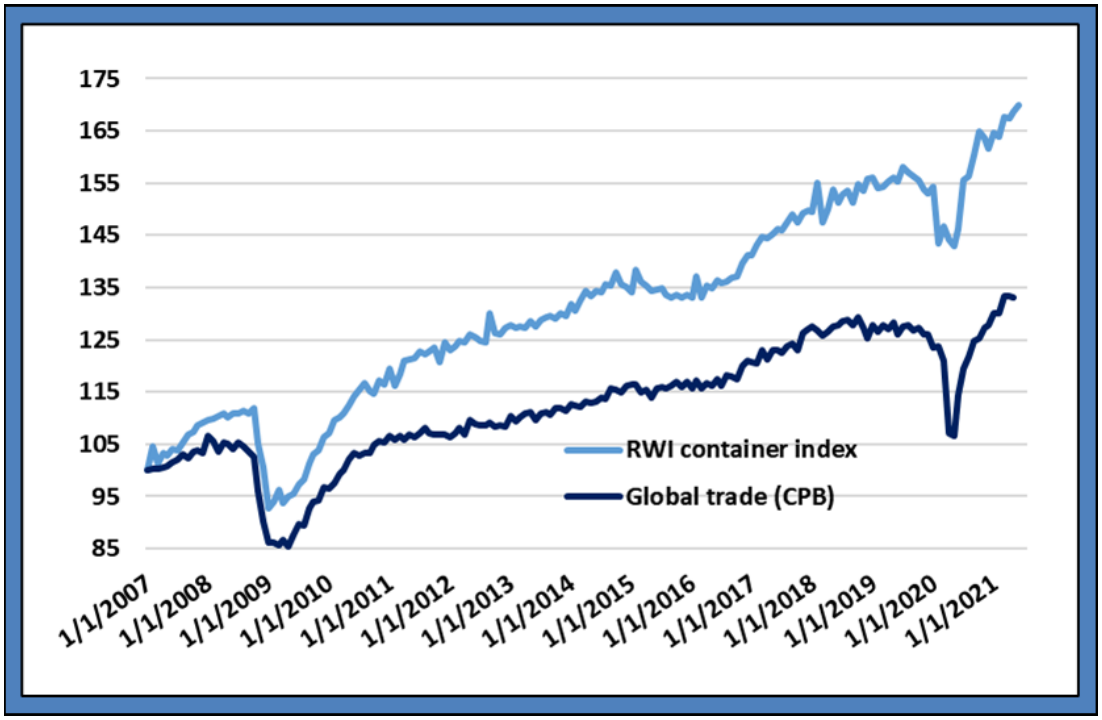
Sources: Argus Media, Refinitiv.

Figure 1 illustrates the recent divergence in performance across commodities. In short, commodity fundamentals do not appear sufficiently aligned to underpin a cross-commodity super cycle in the short term. Longer term, the energy transition might herald a concerted tightening of fundamentals due to a combination of under-investment in hydrocarbon supply and a potential step-change in demand for key metals and minerals resulting from electrification. However, those are issues for the longer term. What cannot be discounted in the shorter term is a degree of ongoing support for commodities as an asset class if broader inflationary pressures due to supply-chain bottlenecks persist in the world economy.

Resurgent World Trade Highlights Supply-Chain Vulnerabilities

Global trade has rebounded more quickly after the 2020 recession than was evident in the aftermath of the Great Financial Recession a decade ago. See Figure 2 on the next page. Trade growth in 2021 is likely to come in at 8%-10%. A combination of accommodative monetary and fiscal policy (including $6 trillion of proposed U.S. stimulus spending), and excess accumulated household savings ($5 trillion in the advanced economies) has sustained demand for container fleets amid economic recovery.

Figure 2
World Trade Rebounds Faster than in 2009/2010



At the same time, the last six months have seen a spate of commodity and manufactured goods supply disruptions due to weather extremes. An exceptional winter freeze hit U.S. energy producers and manufacturers alike in February. More recently, Hurricane Ida shuttered most of the U.S. Gulf's offshore oil and gas production, while power outages have forced shut-downs of Louisiana's refining capacity. A combination of freeze and drought caused by El Niño risks slashing Brazilian agricultural production and exports for two years in succession.

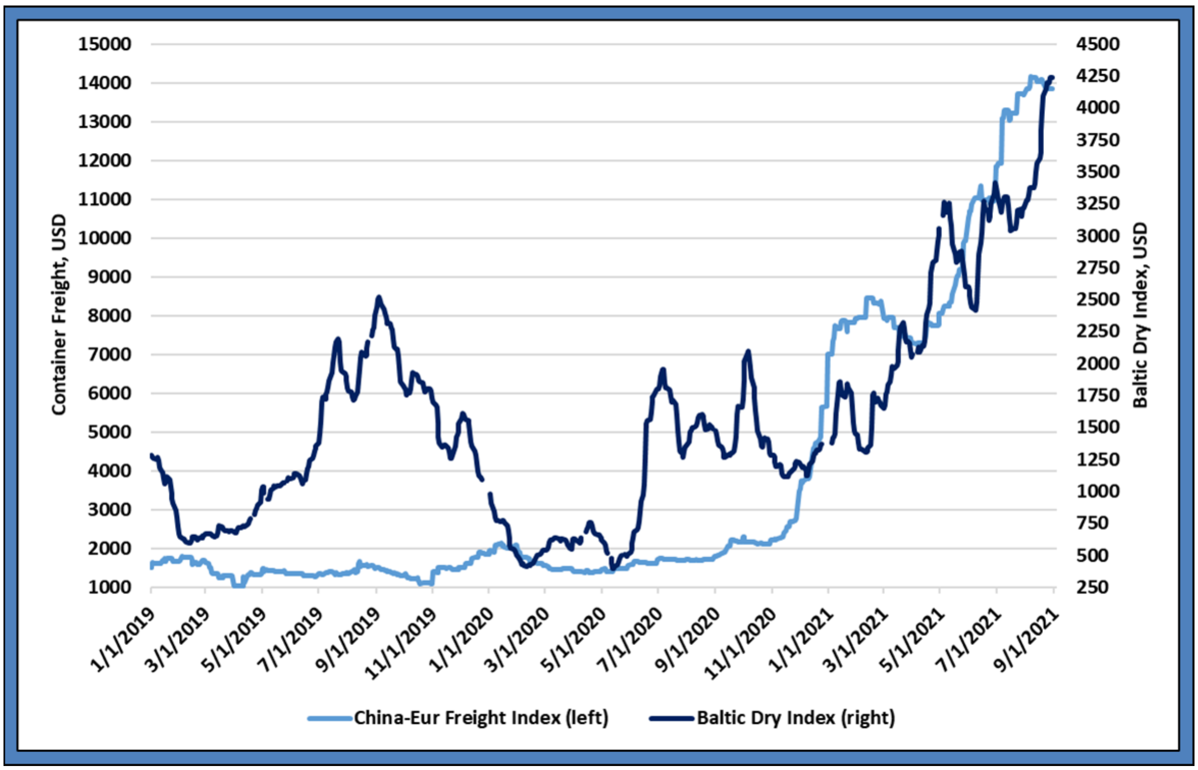
Meanwhile, the worst drought in 55 years in Taiwan has exacerbated a shortage of semiconductors worldwide (Taiwan produces 75% of the world's more complex semiconductors). Again, resurgent demand has coincided with supply-chain shortages to drive prices higher. BMW, Toyota and others have been forced to suspend car production. *Oxford Economics* estimates that supply shortages in the $40 billion global semiconductor market may have reduced 1H 2021 GDP in key automotive producing countries by between 0.1pp and 0.3pp. Moreover, semiconductor shortages are seen persisting through 2022 and into 2023; with limited spare capacity, complex manufacture and high barriers to entry ensure supply chains will remain fragile for the foreseeable future.

In May 2021 the 2.5 mb/d Colonial Pipeline System, which feeds refined products from the U.S. Gulf Coast refining system to southern and eastern seaboard states, was hit by a ransomware attack. Although this instance of cyberattack resulted in a disruption lasting only around one week, it highlighted the rising vulnerability of manufacturing, power supply, energy systems and the marine transportation sector to such attacks. The ongoing trend towards industrial process automation (itself accelerated by a low prevailing cost of capital), and the progressive electrification of the world economy, implies that future attacks are both more likely and potentially more economically damaging.

Shipping Issues Feed Broader Supply-Chain Tightness

Container and dry bulk shipping costs have scaled decade-highs, as shown in Figure 3, amplifying supply-chain cost increases that are feeding broader world price inflation. Sustained higher inflation could see Central Banks respond by raising interest rates in 2022 or 2023. However, despite longer-term concerns over the damage an inflationary spiral (and higher interest rates) could have for economic recovery, more immediately the inflationary narrative has tended to reinforce commodity price rises, with commodities traditionally seen by investors as a good hedge against broader market inflation.

Figure 3
Bulk and Container Freight Surge Continues



Sources: Argus Media, Refinitiv.

Essentially, shippers have confronted a “perfect storm” in recent months, as a strong (if unevenly distributed) rebound in commodity and merchandise goods demand combined with manpower and logistical infrastructure bottlenecks on the supply-side. Varying combinations of depleted inventory, mothballed supply capacity, displaced or idled logistical and transportation capacity and a squeeze on manpower availability have seen the supply side of the global economy, both for manufacturing and selected commodities, slow to respond to resurgent demand. And as noted above, some logistical bottlenecks could persist for another 12-18 months.

Stranded or displaced maritime crews have contributed to market tightness, so too manpower shortages and resultant delays at ports, both for loading and unloading containers and bulk cargo (Brazil and China have been particularly hard hit). Moreover, a recent BIMCO/ICS study highlighted that while short-term dislocations should ease, there is the risk of a growing structural shortage of certified maritime crews, potentially trebling today's 25,000 seafarer shortfall by mid-decade. Nor is maritime transport the only pinch point in supply chains, with widespread truck driver shortages reported throughout Europe, North America and Asia bidding up wage costs. Rail freight rates in North America have also risen sharply in 2021.

Barriers to Trade & Geopolitics

Geopolitical tensions and trade disputes predate the Coronavirus pandemic, but the aftermath of COVID-19 is unlikely to see a speedy resolution of many of the issues. Despite 2019/2020 seeing the signing of a preliminary U.S.-China trade deal, the intra-Asia Regional Comprehensive Economic Partnership (RCEP) free-trade agreement and announcement of an EU-China Comprehensive Agreement on Investment, the new decade may instead be seen in retrospect as a period of fraying international and trade relations.

Many of China's Asian neighbors are trying to reverse their rising economic dependence on the Middle Kingdom. Territorial disputes and trade bans simmer between China on the one hand, and Australia, India and several Southeast (SE) Asian countries on the other. U.S.-Russia and U.S.-China trade relations have been soured by recent sanctions, U.K. and European suppliers are suffering from the trade frictions that have followed Brexit, and political instability in Latin America and the Middle East also has the potential to impede the trade of critical commodities.

It would be wrong solely to focus on China in considering these issues. However, it is the world's first industrial power, accounting for nearly 30% of world manufacturing. Also, taking 10 key energy, metals, agriculture, petrochemical (petchem) and fertilizer commodities, China's imports collectively account for 27% of the world's total trade in those materials. Hence the evolution of China's own policies to boost self-sufficiency, and those of its trading partners to diversify their sources of manufactured goods supply, will profoundly affect supply chains and potentially raise costs in the years ahead.

Energy Transition and Decarbonization

A further key structural influence on supply chains for the post-pandemic era will be the evolution of government targets, mandates and regulations covering energy transition, decarbonization and associated environmental imperatives.

An energy transition will primarily hinge on deeper and broader electrification of the global economy. Recent work by the International Energy Agency (IEA) suggests this could see a six-to-eight-fold increase in demand for key metals and minerals per vehicle or a similar increase in electricity demand compared to current technologies. This increased trade in copper, cobalt and lithium will moreover be additive to world commodity trade. Ultimately, though hydrocarbon fuels will lose market share, they will continue to be traded in huge volumes internationally for decades to come, as also noted in Till (2021).

For the petrochemical sector, the pandemic may in the short term provide a stay of execution for hitherto derided single-use plastics. Without access to the huge volumes of personal protective equipment, sanitization materials and protective wrapping provided by the chemical sector in the last eighteen months, health outcomes for COVID-19 would have been many times worse than they already have been. Plastics recycling as an issue will not disappear however, with major implications for the polyethylene sector in particular. This despite the fact that, on a prevailing cost basis, new plastic is half as expensive to manufacture as recycled plastic.

Finally, with 80% of traded global merchandise moving by sea, supply-chain costs will be heavily influenced by environmental regulation of the shipping industry. While the International Maritime Organization's (IMO's) 2030 GHG emission reduction targets can largely be met from a combination of vessel efficiency improvements, slower sailing speeds and a switch to LNG, longer-term limits for 2050 would require 40%+ of propulsion to come from non-hydrocarbon sources such as ammonia or hydrogen, with clear upward cost implications.

A Policy Impetus Towards Supply-Chain Resilience

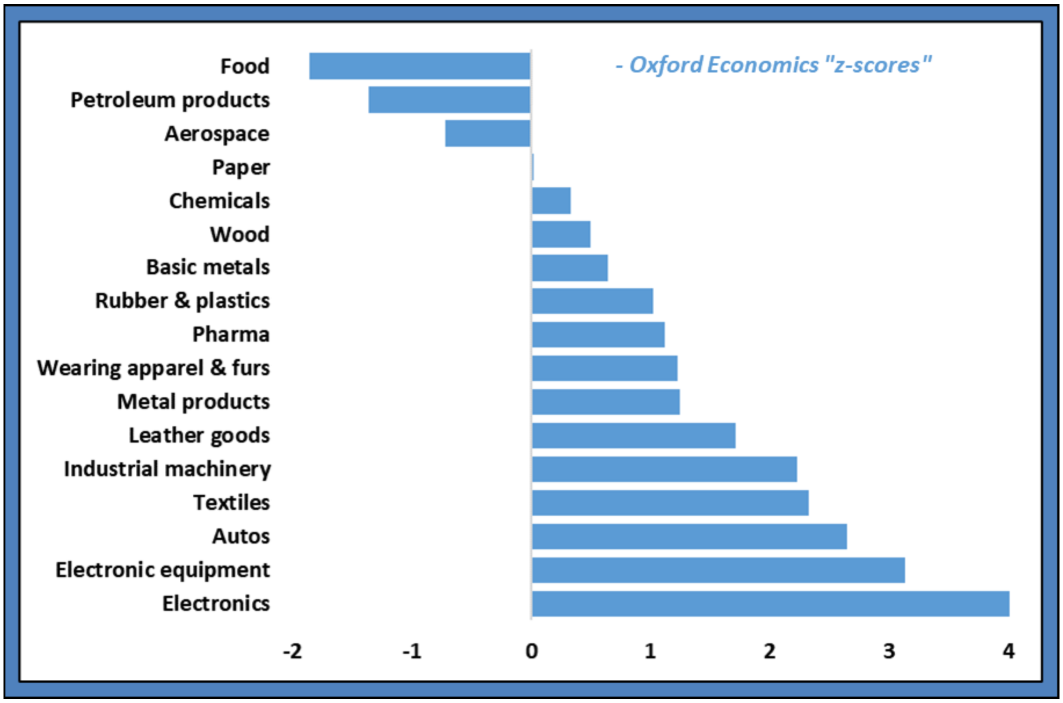
Some of the cyclical factors driving the current bout of supply-chain fragility and inflation will prove temporary. Disruption and dislocations were almost inevitable following the shutdown of the global economy for much of 2020. The more intense among these cost and logistical pressures could ease by 2022 as new manufacturing capacity comes onstream, manpower shortages ease and logistical assets are re-optimized to reflect shifting trade flows. Moreover, cost pressures could recede as growth rates for both the economy and world trade moderate towards historical norms.

Longer term, this "mean reversion" in costs may however be counteracted by other structural supply-chain drivers. The world will not have to wait another 100 years until the next global pandemic. Cyber-crime risks will only intensify as automation and electrification increase. Massive investment running to hundreds of trillions of dollars will be required to diversify the fuel mix by 2050, with new grids, storage systems and shipment infrastructure required. Although the prediction of future changes in earth surface temperatures amid different emission scenarios is prone to massive margins of error, it seems reasonable to assume that extreme weather events could become more frequent. That too implies that greater supply-chain resilience will be necessary.

The pandemic and ensuing supply-chain disruptions is encouraging many countries to develop either indigenous manufacturing capabilities, increased stockpiles or to loosen reliance on any one predominant supplier for a wide range of strategic goods and commodities. There is growing political awareness of a need for supply-chain resilience, even if that undermines supply-chain optimization (cost reduction). By definition, this implies greater future acceptance of higher cost transport and storage solutions, in return for more secure, diversified or local sources of supply.

Nor are the industrial vulnerabilities to supply-chain disruption evenly distributed. As an example, *Oxford Economics* recently cited a ranking of sectoral vulnerability ("z-scores") based on product complexity, sources of imports, current inventory levels and the likely pace of 2021 recovery. See Figure 4 on the next page.

Figure 4
Sector Vulnerability to Supply-Chain Disruption



This suggests that electronics and electrical equipment, automotive, textiles and industrial machinery are the sectors most vulnerable to supply-chain disruption. Although the fuel and petrochemical sectors compare favorably in terms of their own supply-chain fragilities, they too could be prone to unpleasant offtake surprises if supply-chain resilience is not improved across the economy in the months and years ahead.

Predicting the future for commodities, supply logistics and global inflationary pressures while the world continues to grapple with a pandemic is well-nigh impossible. But while today's elevated short-term price inflation could be revised down as cyclical supply bottlenecks recede, we should not be surprised if higher supply-chain costs become structurally embedded for the medium and longer term.

Endnote

David Fyfe presented on topics related this article at the JPMCC's 4th Annual International Commodities Symposium on August 17, 2021. The Symposium's Program Committee Co-Chairs were Dr. Jian Yang, J.P. Morgan Endowed Chair & JPMCC Research Director and Dr. Thomas Brady, Executive Director of the JPMCC.

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What U.S. Dairy Executives Learned from the Pandemic

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Dairy CEOs appear energized and prepared to lead the industry toward a customer-centric post-COVID-19 future.

In the early days and months of the COVID-19 pandemic, the dairy industry faced challenges—such as shifts in supply and demand—as food service demand fell and retail demand skyrocketed. However, the industry ultimately emerged intact thanks to adjustments such as portfolio simplification and manufacturing flexibility. What was the experience like for the dairy industry, and how do executives plan to proceed?

To answer these questions, McKinsey conducted a survey of more than 50 U.S. dairy CEOs in the fourth quarter of 2020. These results were augmented with in-depth interviews. In the survey, we asked executives across the value chain for their feedback on how COVID-19 affected their businesses and how they're thinking about the future of dairy. We've summarized the key trends and findings below and offer three recommendations to address them: expand the talent pool and ways of working, embrace a "One Health" approach, and establish flexible supply chains that can respond to unexpected disruptions. Executives who pursue these suggestions can position their companies for long-term growth.

How the U.S. Dairy Industry Fought Pandemic Headwinds

For dairy overall, 72 percent of surveyed executives reported neutral or improved margins in 2020; this generally holds across small and large (more than $1 billion in revenue) companies and across subsectors, including retail, packaged goods, food service, ingredients, processors, suppliers, and distributors. Certain product categories outperformed, driven in large part by a shift toward eating more at home: 54 percent of dairy consumers reported cooking more since the start of the pandemic. As a result, butter retail sales increased 32 percent in 2020, and fluid milk bounced back from negative growth and saw a 206 percent increase in volume sales across retail and food service in 2020, as compared with four years prior. What factors enabled some dairy companies to emerge relatively unscathed?

Operational Shifts (and a Bit of Luck) Helped Mitigate Supply Challenges

Executives may recall empty dairy shelves during the first two months of the pandemic, juxtaposed against images of U.S. dairy farmers pouring out tanks of milk. Dairy Farmers of America estimated that "milk dumping" produced up to 3.7 million gallons of waste a day in April 2020 (Corkery and Yaffe-Bellany, 2020). This supply-and-demand mismatch early on was created by an abrupt shift in demand, from food service to retail. Many producers and co-ops, locked into foodservice supply contracts, were left without an outlet, while many manufacturers had foodservice-specific production facilities that were unable to shift seamlessly toward retail. This abrupt shift of the dairy market from food service to retail overwhelmed distribution warehousing and logistics in the short run, further disrupting the dairy supply chain.

While nearly all dairy companies struggled to adjust to the new normal during the early stages of the pandemic, most capitalized on increased retail demand through inherent or reactive operational flexibility. The following four factors contributed to their success:

- *Manufacturing and Channel Flexibility.* Seventy-three percent of dairy executives reported being able to shift production from food service to retail between March and April 2020, a move mostly dependent on the preexisting position of plants. Processors interviewed in October 2020 communicated a feeling of luck that their plants were interchangeable or that excess capacity in retail plants allowed them to meet the swell in demand. One CEO said, "We inadvertently had the right system for the crisis and were able to pivot manufacturing from food service to retail by flexing our plants." This highlights the value of flexibility and how systems could benefit from such adaptability in the future.

- *Collaboration across the Value Chain.* Dairy executives referred to the unprecedented collaboration and communication required to address supply-chain disruptions. Producers, processors, packagers, distributors, and retailers coordinated among themselves, as well as with local and state authorities, to ensure products reached shelves. According to one executive, "Constant communication and give-and-takes within our supply network allowed us to quickly adapt our products and get them to consumers."

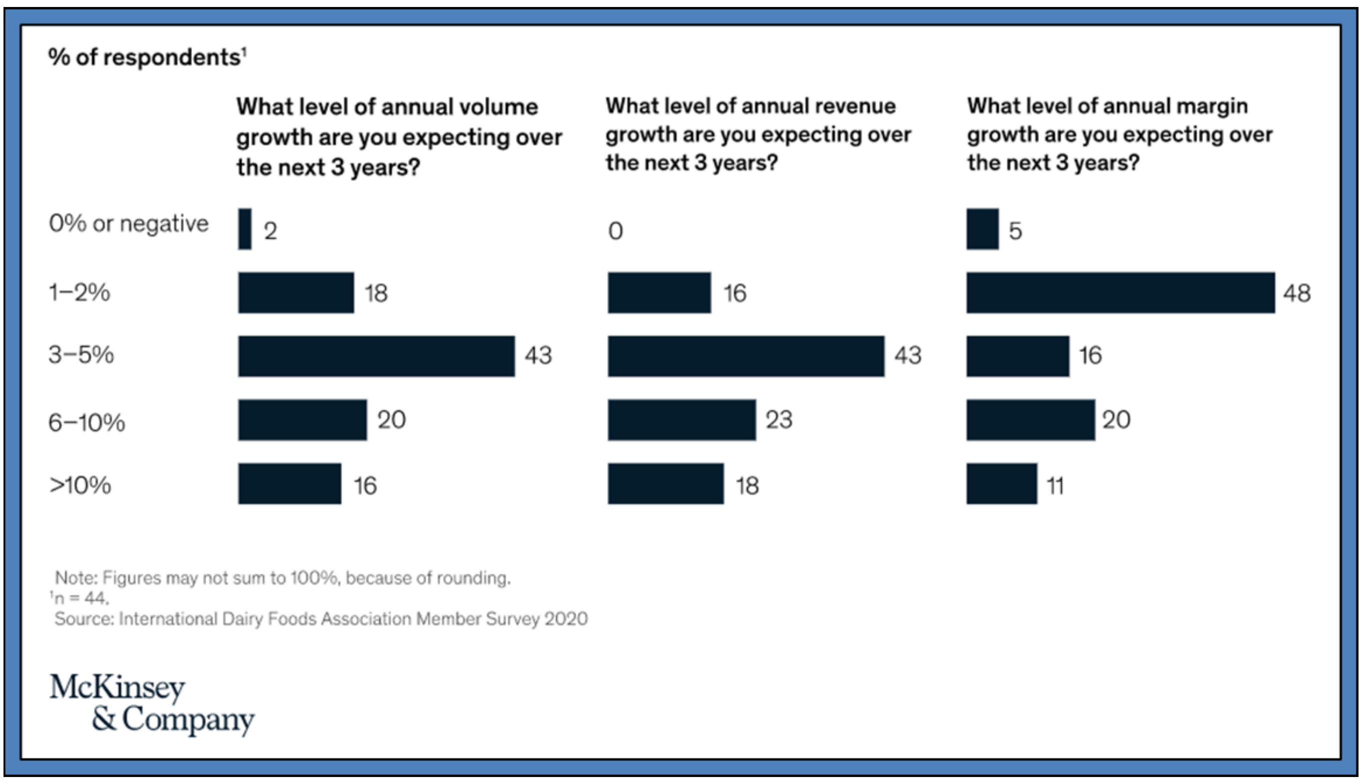
- *Simplification.* Stock keeping unit (SKU) rationalization characterized much of the crisis. To meet increased demand and competition for space in distribution and retail networks, companies moved away from a historic focus on variety and moved toward the basics. In the words of one executive, "We're just offering chocolate, vanilla, and strawberry ice cream, given [retail] real estate constraints—and consumers are happy with that!" Forty-one percent of processors interviewed reported pursuing SKU rationalization, especially in the short term—but some have plans to also streamline their portfolios in an ongoing way.

- *Adaptation to Remote Work for Employees Not on the Front Line.* While executives communicated the challenges of remote work, they also appreciated important silver linings. Most notably, remote work has widened the talent pool by loosening geographic constraints and opening opportunities in areas that typically present a challenge for the industry, such as engineering support roles. One executive said, "We've struggled with talent in the past but are now able to look at a broader set of candidates."

What Executives Think about the Future

Survey respondents are optimistic about future growth and recovery from the pandemic. In fact, 84 percent expect annual revenue growth of at least 3 percent over the next three years, and most expect favorable growth on volume and margins (Exhibit 1). This optimism is likely driven in part by the 70 percent of executives who believe the negative impact of COVID-19 will subside during 2021.

Exhibit 1
More Than 80 Percent of Dairy Executives Expect Strong Top-Line and Volume Growth Over the Next Three Years



However, three uncertainties are top of mind for executives: shifting consumer preferences, the changing landscape of retailers and channels, and finding new ways to use technology. Agility is key to addressing these issues.

Shifting Consumer Preferences

Dairy executives are 15 percentage points less confident in their ability to identify consumer trends today than they were in 2019: 28 percent in 2020 versus 43 percent in 2019. Nonetheless, 66 percent of executives report increasing their level of investment in innovation, with a particular focus on sustainability, health and wellness, and convenience; 56 percent report dedicating resources to sustainable packaging, and 52 percent plan to launch protein-enriched or pre- or probiotic products in 2021. Executives continue to focus on nondairy alternatives, which are generally perceived by consumers as healthier and more environmentally sustainable (representing strong drivers for the nearly 50 percent of consumers who purchased dairy alternatives during the pandemic); 30 percent of CEOs report interest in adding plant-based products to their product portfolio. Also, 29 percent of executives are investing in packaging that extends a product's shelf life, a convenience consideration for consumers looking for at-home stocking options.

Changing Landscape of Retailers and Channels

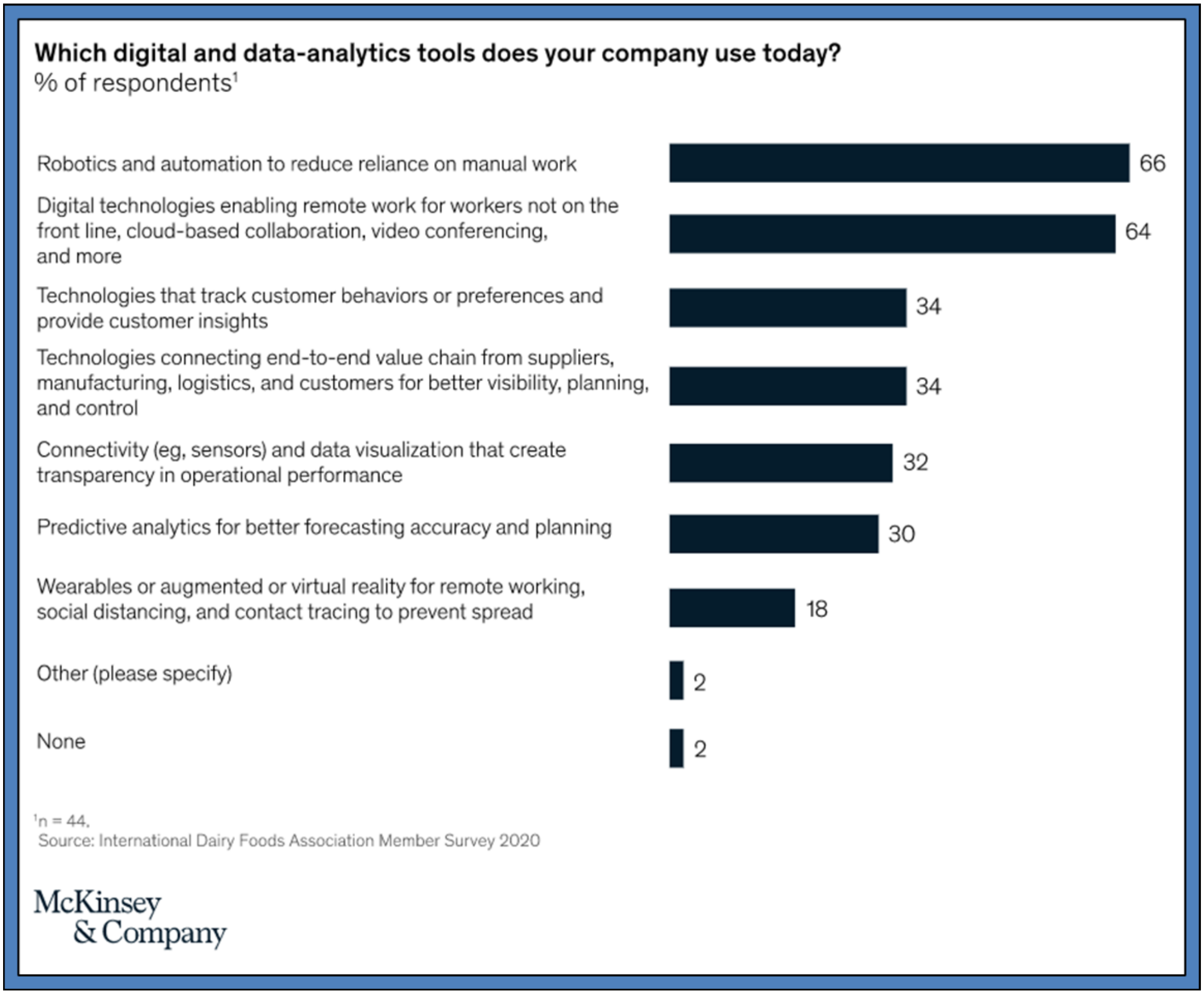
Dairy executives recognize that shifts toward e-commerce may endure, and they are investing accordingly. Despite concerns over smaller margins, 67 percent of CEOs report they are investing in e-commerce. Examples include taking steps to strengthen their partnerships with retailers to better coordinate online marketing, investing in online platforms, and innovating packaging for optimal last-mile delivery.

Finding New Ways to Use Technology

Technology and digital and analytics enable dairy executives to make improvements in important areas such as supply and demand planning, operational efficiencies, and customer engagement and insights. In fact, two-thirds of surveyed executives report using robotics and automation to reduce manual work in plants. In addition, 30 percent of respondents report using predictive analytics for forecast-based planning, and 34 percent use technologies that address end-to-end value-chain visibility, planning, and control; see Exhibit 2 on the next page.

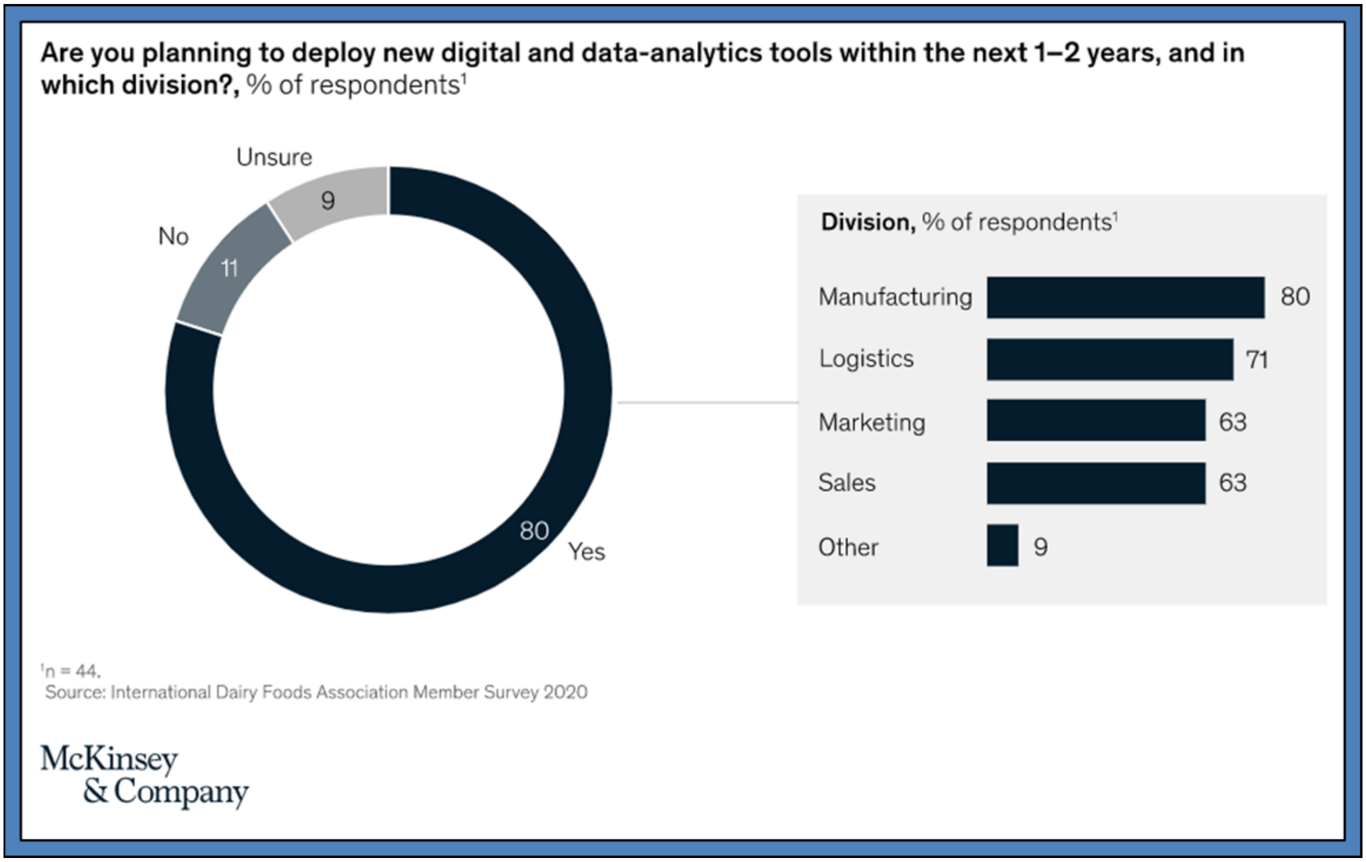
But CEOs believe more can be done: only 2 percent reported having "very strong" digital and analytics capabilities, and only 16 percent believe they are optimally and regularly processing data to generate meaningful insights.

Exhibit 2
Dairy Technology Today is Mainly Used to Achieve Labor Efficiencies



As a result, 80 percent of CEOs report that they plan to deploy new digital and data-analytics tools within the next one to two years, mainly focusing on manufacturing and logistics. In addition, 63 percent of executives report plans to invest in marketing and sales, implying a desire to prioritize strengthening consumer-insight capabilities; see Exhibit 3 on the next page.

Exhibit 3
CEOs Report They Plan to Invest More Heavily in Digital and Data-Analytics Tools within the Next One to Two Years, with a Focus on Manufacturing and Logistics



What is Most Important to U.S. Dairy CEOs?

During one-on-one interviews, we posed questions aimed at uncovering the key themes on the minds of dairy executives. As in 2019, themes that are top of mind consistently include risk and volatility, consumer insights, and evolving behavior (especially of millennials). The difference in 2020 was an overall sense of optimism and a shift toward embracing ideas previously perceived as threats, such as an increased focus on the environment. For instance, some dairy companies are embracing the consumer and market interest in the environment by pursuing initiatives such as regenerative agriculture programs (Cornall, 2020).

What Keeps Dairy Executives Up at Night

Health and Safety. Consistent with prior years, food safety is top of mind for executives. Furthermore, at the end of 2020, executives cited employee health and safety as a number-one concern, driven in part by COVID-19.

Risk and Volatility. Executives are concerned about volatility and the big unknowns regarding financial and regulatory pressures, especially given a new U.S. political administration.[1]

Changing Consumer Preferences. Consistent with their reported decreasing confidence in understanding consumers, CEOs say they are concerned about keeping pace with frequently shifting consumer preferences.

What Dairy Executives are Most Excited About

Innovation. Despite the pandemic-driven return to basics, executives anticipate gearing back up to diversify their portfolios.

Renewed Consumer Focus on Dairy. Buoyed by the return of dairy during the crisis, executives hope to see a sustained interest across categories. They are especially optimistic about health- and wellness-centric products.

Missions. CEOs are increasingly focused on social-welfare initiatives, especially around environmental sustainability. Company culture and identity also emerged as more critical today, given disconnected work environments and the importance of keeping employees engaged.

Dairy CEOs appear energized and prepared to lead the industry toward a customer-centric postpandemic future.

Paving the Path Ahead

Here are a few important takeaways from the pandemic for dairy executives:

<u>Expand the Talent Pool and Ways of Working</u>

Where remote work is possible, dairy executives should consider seeking talent beyond traditional geographic constraints. Employers can assess the degree of in-person interaction necessary for a non-factory-based role, for instance, to decide whether the person in that position could work remotely. Several high-tech companies are leading the way by offering to remove the requirement for workers to show up on-site.

Embrace a One Health Approach

A One Health approach encourages cross-sectoral and cross-disciplinary collaboration at local, regional, national, and global levels to support the health of humans, animals, and the environment. To advance this goal, executives could pursue two actions:

- Identify evidence-based positions on dairy's role in public health.

- Build cross-sectoral, public health–focused partnerships—for example, with other animal-derived food-industry groups, public health institutions, and academia—to address priorities such as environmental sustainability, health and wellness, food security, food safety, and antimicrobial resistance.

Establish Flexible Supply Chains

The year 2020 proved the value of resilient and flexible supply chains for companies that had made the efforts to build them. The next phase will couple active monitoring of the supply chain to anticipate disruption with the implementation of flexible formulas—for example, the ability to produce with different components offering similar functions.

Conclusion

Dairy executives are optimistic about the future of their industry, but they have to translate that optimism into action. Regardless of company type, size, or complexity, future success depends on their ability to achieve clarity on strategic priorities—as well as on the systems to support agile execution.

Endnotes

The authors wish to thank Diane Guité, Alina Malinauskaite, and Isabella Maluf for their contributions to this article.

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1 Risk and volatility are prevalent consumer goods–industry concerns. For more on these concerns, see Alldredge *et al*. (2021).

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Christina Adams is a leader in McKinsey & Company’s consumer goods practice, with deep experience across commercial optimization, growth strategy, and optimizing portfolio and network complexity. She regularly looks at topics relating to how food and beverage consumer goods companies can adapt and grow in the changing consumer and retail landscape.

Christina started her career at Procter & Gamble working in brand management in Cincinnati, Ohio. Christina earned both her B.A. and M.B.A. from Harvard University. She is a native Oklahoman.

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Prior to McKinsey, Ludovic spent 13 years at Danone sourcing all fluids and dairy ingredients for North America, while also serving as a board member on the Quebec Dairy Council. He also spent 5 years at Coca Cola/Glaceau in manufacturing and sourcing. Ludovic earned his Master’s in Automation from Ecole Nationale Superieure des Mines de Paris in France and an M.B.A. from the Wharton School at University of Pennsylvania.

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Roberto leads McKinsey’s Agriculture Practice globally and the firm’s consumer operations work in North America. As an advisor to agricultural and food and nutrition companies, Roberto brings on-the-ground experience in the Americas, sub-Saharan Africa, and Western Europe. He partners with executives to address their most pressing strategic and performance issues, including growth, merger management, commercial excellence, supply-chain optimization, and organizational restructuring.

Since joining McKinsey, Roberto has built extensive expertise designing growth strategies and delivering performance improvements across commercial and supply-chain operations. Working with companies across the globe, he has led efforts to assess value-chain vulnerabilities and growth opportunities in the dairy, protein, row-crops, oilseeds, and starch and sweeteners sectors. Roberto also supports complex postmerger situations, defining integration approaches and ramping up value-capture teams.

Roberto has contributed to several of the World Economic Forum's major reports on sustainable agriculture. He is fluent in English, Portuguese, and Spanish.

Open Outcry Traders History Project Captures Traders' Stories from Bygone Era:
Their Stories Live on Even if They Don't

John Lothian
Founder and Publisher, *John Lothian News*

Survival as a trader in the open outcry futures trading pits was never easy. Beyond the normal economic risks of trading, the growing pains of new financial futures markets starting in the 1970s caused many headaches and heartbreaks, as did macroeconomic events in the traditional commodity markets.

Then electronic trading created an existential threat to open outcry trading and its traders.

John Lothian News (*JLN*) seeks to capture the stories of the open outcry traders before they perish for good. In March 2019, *JLN* announced the Open Outcry Traders History Project. It was modeled after the Veterans History Project signed into law by then-President Bill Clinton in the 1990s.

JLN had started down the road of recording derivatives industry history on video when we embarked on a multipart series titled, "The History of Financial Futures," in 2011. We were afraid then that the pioneers who created the modern era of markets and finance were disappearing when Chicago Corporation founder Jack Wing passed away.

Too many traders are already gone, taking their colorful and sometimes NSFW (Not Suitable for Work) stories with them. Open outcry trading was an important method of commerce in the U.S. for much of the nation's history. We needed to capture the stories of the people who participated in open outcry markets in the U.S. and around the world, from futures, equities and options traders.

Our first interview was with Leo Melamed, the chairman emeritus of the Chicago Mercantile Exchange (CME) and someone who found his way to the CME in the 1950s when it was on Franklin Street in Chicago. Leo was among those who found a career in the markets by accident.

Melamed wound up at the CME when he answered an advertisement for a runner's job that he thought was for a law firm. He was in law school at the time and a friend told him about the job listing in the *Chicago Tribune* for a law firm named Merrill Lynch, Pierce, Fenner & Beane.

Melamed applied and was hired; however, the firm was not a law firm but a brokerage firm with operations at the Chicago Mercantile Exchange.

As a trader, Melamed's bias is to be a bear and make money from the short side of the market.

There were many reasons he gave for this bias, including the public's bias to only go long. He said, "The public does not know how to go short."

During the 1970s oil embargo, at a time when the CME's International Monetary Market (IMM) currencies were still illiquid nascent contracts, Melamed got caught short the Swiss franc. "The Swiss franc went crazy," he said, adding he was trapped and could not get out of his position for days, which cost him a lot of money. By the time he did finally cover his short Swiss francs position, it was his worst trade.

Melamed said he went broke three times, all in his early days when he was trading eggs and onions at the Chicago Mercantile Exchange. After going broke the last time, on September 13, 1969, he went down to the trading floor after the close to look amid the mess of paper on the trading floor for the paper from the calendar entry for September 13. He found it and had it framed and vowed never to go broke again.

Our first series of interviews also included early adopters of financial futures at the Chicago Board of Trade (CBOT). Many times they learned lessons the hard way because of the newness of the financial futures contracts and their inexperience, despite quality academic training.

Gary Sagui was steeped in the efficient market theory after earning a Master's degree from the University of Chicago. However, he found the markets were inefficient when the Treasury futures quarterly roll occurred. Traders with long positions in Treasury bonds, not wanting to take delivery, would be first movers and liquidate their longs before the delivery period. Then the shorts, who were required to hold their positions in the months with the most open interest, would be forced to shift their positions to the next month. Despite everyone knowing this was going to happen, per efficient market theory, Sagui and his brother were able to regularly profit from this inefficiency.

The Saguis would eventually put on "insanely" sized positions, representing as much as 10% of total bond open interest, before learning not to trade so big the hard way. They never traded that big again.

Bill Dudley joined Merrill Lynch after the Army and his first job was getting coffee for Treasury traders. Eventually, he came to Chicago to work for Hornblower & Weeks, who gave him a CBOT membership that allowed him to trade the then-new Government National Mortgage Association (GNMA or Ginnie Mae) futures.

Dudley later found himself with a position in a failing commercial paper contract, whose open interest dropped to just two contracts, with Dudley short the two remaining contracts open. He suddenly realized he had no chance of finding the commercial paper to make the delivery and if he defaulted on the contract he would lose his job and be kicked out of the CBOT.

Near the last day of trading, a Continental Grain trader came into the commercial paper pit and asked "What's here?" Dudley responded, "Offered at 30." The Continental trader, representing the long, said "Sell 2 at 20." Dudley said "Sold." Then Dudley did something to make the Continental trader look good. The market had no open interest, but Dudley offered the market limit down. Since the Continental trader liquidated the customer's long position before the market was offered limit down, Dudley ensured it looked like the customer received a good fill.

Dudley's best trade ever was a $500,000 loss, but a trade that could have been five times worse. The issue Dudley and his customer had that led to the loss was a structural misunderstanding of the dynamics of the GNMA contract duration versus the 30-Year Treasury Bond futures. The problem Dudley could not figure out while in the trade eventually led to the GNMA futures contract failing and being delisted.

Capturing the stories of open outcry traders before they pass away proved prescient for a couple of our interviews. We interviewed longtime Chicago Mercantile Exchange Chairman Jack Sandner before he passed away in 2020. Sandner was a Notre Dame-trained lawyer who found himself representing the CME president, Everett B. Harris. Harris tried to recruit Sandner to CME membership by inviting him to a holiday party held by CME Chairman Leo Melamed.

When Sandner attempted to enter the holiday party, he was rebuffed by a couple of traders at the door who told him that it was Leo Melamed's party, not Everett Harris' party. A fight broke out and Sandner, a former Golden Gloves boxer, knocked out one of the traders, who Sandner later learned was a prominent cattle trader.

Sandner would eventually give the CME a look, become a member, join the board of directors and become its longest-serving chairman.

Sandner was a newly elected chairman of the Chicago Mercantile Exchange during the Hunt silver market corner in the late 1970s. While the CME had a silver futures contract at the time, it was in the live cattle market -- where the Hunts were also active -- that Sandner found himself on the wrong side of the market.

During a Chicago Mercantile Exchange board meeting, Sandner and the board made the decision to force the Hunts from their long cattle positions. Sandner was also long live cattle futures, with a limit-size position. The Hunts had over-sized positions well beyond speculative size limits, as they had filled out the exchange's forms and declared themselves hedgers. Sandner and his board voted to "blow them (Hunts) out of the market," he said.

After the board decision, the live cattle market went down the limit three days in a row, causing large enough losses for Sandner that his friend and mentor Leo Melamed and his partner Maury Kravitz called Sandner's home and talked to his wife. They told his wife they were worried about Jack as he had taken severe losses. Sandner described the market action as "destroying him."

When Sandner came home, his wife told him Melamed and Kravitz had called and asked if there was something he needed to tell her. He told her no, but said that now that she knew, he was headed back down to the exchange to wait for the market to open rather than pretend to try to sleep.

After three days of limit down and a preliminary call of limit down the fourth day before the opening, Sandner said he was told the market was getting some buy orders coming in and might not open lower. Closer to the opening, Sandner was told there were plenty of buy orders coming in, and his friend Terry Brennan said he could get him out of the market.

However, Sandner said no, he was going to stick with the losing long position. His friends kept badgering him to "get the hell out." Sandner finally agreed to get out if the market were to trade 15 points lower than the previous close. The market traded 10 lower, then "turned on a dime," Sandner said and shot to limit-up. It traded limit up for two more days, then opened higher the next day and Sandner finally liquidated his limit position in live cattle. It ended up being his best trade ever. He made about $100,000 on the trade. After he got out of the position, he went to St. Peter’s Church in downtown Chicago and thanked the Almighty.

Larry Abrams found his way to the market via a good deed. He and some friends stopped to help a car stranded on the side of the road during a blizzard on a ski trip to Park City, Utah. The next day as Abrams was getting on a ski lift, he was paired with the man whose car had broken down. The man was a member of the Chicago Board Options Exchange (CBOE), and by the time they were done with the ski lift ride, Abrams knew what he wanted to be: an options trader.

Abrams was from Philadelphia, so he checked out the Philadelphia Stock Exchange for opportunities. He was hired by Cooper Neff as a market maker.

However, Abrams’ exchange trading would later bring him to Chicago, after a stop at Kansas City Board of Trade (KCBT), where he was to set up a futures trading operation for Cooper Neff to hedge their Value Line Index options trades with the nascent Value Line Index futures.

Abrams and another trader from Philadelphia were not well received by the old-time wheat traders and their progeny at the KCBT. Abrams was given a very unsentimental nickname and was referred to with various anti-Semitic incivilities. When Abrams was asked by Cooper Neff’s head trader in Philadelphia to sell 600 contracts of Value Line futures, a sizeable order that the pit had never seen before, it created all kinds of trouble.

Abrams took the order and went into the Value Line pit and asked, “What's there?” The other trader from Philadelphia, representing Philadelphia Trading, which later became Susquehanna, said, “50 bid.” Abrams yelled, “Sold.” How many, the Philly trader asked. Abrams said “100.” Abrams again asked, “What’s there?” The Philly Trader again said, “50 bid.” Abrams said, “Sell you 500 at 40.” The Philly trader said, “Sold.”

Both traders were rushed by other traders in the pit who had witnessed this huge trade (by KCBT standards at the time) and called them every name in the book. The traders accused them of pre-arranged trading. Eventually, exchange security showed up and whisked Abrams and the Philly trader away from the trading floor, saving them from a potentially dangerous situation.

The Commodity Futures Trading Commission (CFTC) office was across the street from the KCBT, and an official came over to interrogate them about the trade. Abrams and the other trader were barred from the floor for 10 days while the matter was investigated. In the end, the trade turned out to be legitimate and both were restored to full membership rights.

The traders of the open outcry era came from many different places, with varying levels of education and direction in their lives. Once they found the action of the open outcry markets, they were hooked. The open outcry era is slipping into history, as are the traders, but their legacy lives on.

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John J. Lothian is a Chicago-based financial media executive and entrepreneur. He is the founder and publisher of *John Lothian News*, MarketsWiki, CryptoMarketsWiki, MarketsWiki Education and MarketsReformWiki. Lothian is also a Commodity Trading Advisor (CTA) and industry consultant. In addition, he is the Executive Chairman and CEO of John J. Lothian & Company, Inc.; is a principal with John J. Lothian Managed Futures, LLC, a National Futures Association member Commodity Trading Advisor; and serves on the U.S. CFTC Technology Advisory Committee. He was named to the latter committee in June of 2012.

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Interview with Daniel Jerrett, Ph.D.

Chief Investment Officer, Stategy Capital LP

Dr. Daniel Jerrett, Ph.D., is the Co-Founder and Chief Investment Officer at Stategy Capital LP and is a member of the JPMCC's Industry Advisory Council. Dr. Jerrett also lectures for the JPMCC's Professional Education program at the University of Colorado Denver Business School and is a *GCARD* Contributor.

We are delighted to interview Dr. Daniel Jerrett, who is the Co-Founder and Chief Investment Officer at Stategy Capital LP, a global alternative investment management firm. Dr. Jerrett has more than 15 years of experience developing and implementing forecasting models, spanning both the private and public sectors. He has spent time in the investment management industry, state, and local governments as well as consulting with Fortune 500 companies.

Dr. Jerrett also teaches courses in econometrics and forecasting at the J.P. Morgan Center for Commodities (JPMCC) and is a member of the JPMCC's Industry Advisory Council. In addition, he recently contributed an article to the *GCARD* on measuring commodity super cycles and presented on this topic at the JPMCC's 4th Annual International Commodities Symposium.

In this issue's interview, Jerrett describes his career along with providing his view on whether we are in another commodities super cycle. He then discusses his involvement with the JPMCC. The interview concludes with his advice for students and young professionals on the commodity industry.

How did you get involved in alternative investments, particularly commodities, and how has your career evolved?

My interest in commodities began in graduate school while working on my Master's in Economics at DePaul University in Chicago. My thesis was a study on the cross-country determinants of poverty. The deeper I dug into the data, the more I realized how important commodities were to many countries' long-term economic growth. I was intrigued by the cyclical nature of commodity prices.

That interest led me to start a doctorate in Mineral and Energy Economics at the Colorado School of Mines. I attended a research conference in the fall of 2005 and had the opportunity to meet Alan Heap of Citigroup. Alan was presenting on super cycles in metals prices. That was the motivation for my dissertation and ultimately the first peer-reviewed academic research published on measuring super cycles.

My career has led me in many different directions. I have spent time in both the public and private sectors, but all my experience has centered on combining macroeconomics and statistics. I worked as a macroeconomist at Putnam Investments where I was responsible for developing a series of factor models for global fixed-income portfolios. In addition, I managed fundamental trading positions in emerging market currencies and sovereign rates. Although commodities were not directly considered in the investment mandate for the portfolios I supported, I quickly discovered how important commodities were in understanding fixed-income markets. This is particularly true of emerging markets.

My interest in global capital markets expanded and I spent five years privately consulting with central banks, hedge funds, and investment management firms. I had the opportunity to see how many of these institutions were modeling global markets and how they thought about portfolio management. One thing that stuck with me was the race to implement machine learning and Artificial Intelligence (AI) tools.

All these experiences led a long-time investment colleague, Joel Fortney, and I to contemplate an investment strategy that could bring together our expertise and enable us to take the best of what we have learned and implement it in an unconstrained way. We founded Stategy Capital LP in 2020 and launched our first strategy, the Stategy Global Macro Fund LP, in January of 2021. The fund leverages our cross-asset expertise and backgrounds implementing systematic fundamental processes across a wide range of asset classes including commodities and digital assets. The entrepreneurial nature of alternative investing provides us more flexibility and focus to apply research and actively manage portfolios.

As my career has progressed, I have realized how important continual learning is to success, especially in the alternative investment universe. We are witnessing the evolution of new asset classes, such as digital assets, and more powerful quantitative methods to help understand and model assets. It is both humbling and exciting to be investing during a time of such substantial technological innovation.

You recently contributed an article to the GCARD on commodity super cycles which was cited by the Wall Street Journal and the World Bank. Can you summarize your paper's analysis and its conclusions?

The increase in commodity prices over the last year has reignited the topic of super cycles. My motivation for writing the article was to apply a framework that was originally developed in 2008 to the current discussion. One of the key tenets of the super-cycle hypothesis was that super cycles are demand driven and have been associated with periods of industrialization and urbanization of an economy. Past super cycles are associated with the industrialization of the U.S. in the late 1800s, post-war reconstruction in Europe and Japan, and the most recent super cycle in China in the early 2000s. These were major economic transitions that lasted for decades.

The super-cycle discussions occurring in early 2021 were focusing on the recent price appreciation and simultaneously the discussion of decarbonization, electrification, and the move to green infrastructure. I felt those two topics needed to be addressed separately.

The rapid acceleration in prices experienced as the global economy started to recover from the Covid-induced recession in late 2020 appeared to be driven more by business-cycle factors than by super-cycle factors. China's economic recovery, low interest rates, and low inventories in many commodities all may have helped fuel the price increases seen over the past year. These are more transitory in nature than the forces that generate and sustain super cycles.

The discussion of a coordinated global movement of decarbonization, electrification, and infrastructure upgrades could create sustained demand in many commodities required for a "green" economic transition. I don't believe those forces are at play currently but could be coming throughout the next decade. It is also worth noting that future super cycles could look different from the three prior cycles. Past super cycles were not only associated with industrialization and urbanization, but they were also broad-based across commodities. A future "green" super cycle may involve smaller, more specific groups of commodities.

The original statistical analysis utilizing band-pass filters was updated through 2020. There was no statistical evidence that a new super cycle was underway based on price increases seen over the past year. Both the 2008 research and the latest *GCARD* article were not intended to prove or disprove the existence of super cycles. Hopefully the research could be used to frame the discussion of super cycles with a focus on data and measurement.

As a member of the JPMCC's Industry Advisory Council, which initiatives of the JPMCC are you most proud of?

I have been associated with the JPMCC since 2013. Watching it develop into an internationally recognized research center has been exciting. I have been directly involved with the development and delivery of the professional-education curriculum. This has been the most rewarding part of my tenure at the center.

Our courses have brought together professionals at all career levels and from many different industries and roles. This diversity enhances the instruction and discussion during courses. Participants not only learn from the instructors, but from each other.

The J.P. Morgan Center for Commodities is positioned to be an international leader in both applied research and professional education. Very few institutions have the resources and network of experts that can support the continued growth of a professional education program that encompasses market structure, trading, and quantitative analysis across all commodity complexes. I am excited to see the professional education curriculum expand and meet the needs of an ever-changing global landscape.

As an adjunct professor at the JPMCC, what are some of the trends that you see in terms of student interest in commodities?

The center continues to see increased interest from both undergraduate and graduate students. As our course offering has deepened, students are starting to understand how big of a role commodities play in the global economy and how a specialization in commodities can complement their degree(s).

Increasingly, students are interested in developing quantitative skillsets. Interest in learning programming languages such as Python and R and in being fluent and able to develop trading and forecasting models in those languages has increased in recent years.

I think students are increasingly facing a job market that is demanding a set of quantitative skills that a few years ago would not have been required.

What advice can you give to students and young professionals who are interested in a career in the commodities markets?

My advice would start with being intellectually curious and open to many opportunities. I came out of graduate school in the middle of the Financial Crisis in 2010. At that time, many of the positions and organizations that would have been traditional fits for a Ph.D. in mineral economics had stalled hiring or eliminated positions due to the recession.

I started my career working as an economic advisor for the Governor of Colorado. My role included understanding the impact of mining and energy extraction on the state economy. Although not where I thought I would begin my post-graduate career, my knowledge and expertise in natural resources and statistical modeling played a crucial role in advising both the Governor and state legislature.

My quantitative skillsets have allowed me to move between the public and private sector and various industries. Ultimately, it helped with the creation of Stategy Capital and launching an alternative investment fund.

I think acquiring fluency in quantitative methods is becoming increasingly important in all areas of commodity markets. Whether someone's interest is to become a trader, a fundamental research analyst, or a senior manager, the ability to synthesize data and understand how commodities interact with other markets and the overall global economy demand a quantitative framework.

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

Announcement of *GCARD*'s Best Article Award

Dr. John (Hua) Fan, Ph.D., Senior Lecturer in Finance at Griffith Business School (Australia), with the *GCARD* Best Article Award. Dr. Fan is also a *GCARD* Editorial Advisory Board member.

Congratulations to Dr. John Fan of Griffith Business School (Australia) on winning the *GCARD*'s Best Article Award! Dr. Fan's research digest article summarizes his co-authored paper with Dr. Di Mo of RMIT University (Australia) and Tingxi Zhang of Griffith Business School (Australia) on "The 'Necessary Evil' in Chinese Commodity Markets."

Dr. Fan's research digest article was published in the Winter 2020 edition of the *GCARD* and is available here. The comprehensive paper was published this year in the *Journal of Commodity Markets* and is available here.

"The paper investigates the impact of enormous capital inflows into commodity futures markets in China. Mimicking the positions of both passive long and systematic long-short speculators, the study finds increased speculation does not give rise to higher volatilities and co-movements, nor distorts the market's association with economic fundamentals. Moreover, long-short speculators who trade on commodity fundamental information contribute positively to price discovery by reducing the broad market volatility and cross-correlation with stocks. Overall, intensified speculation did not have an adverse impact on the broad Chinese commodity futures market."

The four judges who selected the Best Article in the past year's *GCARD* were Nick Vasserman, Founder and CIO, Integrated Portfolio Intelligence, LLC; Dr. Tom Brady, Executive Director, J.P. Morgan Center for Commodities (JPMCC); Dr. Jian Yang, CFA, J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Discipline Director and Professor of Finance and Risk Management at the University of Colorado Denver Business School; and Hilary Till, the JPMCC's Solich Scholar.

The judges selected the winning article based on the following four criteria: Novelty and Insight; Demonstration of Technical Expertise; Potential Usefulness to Industry; and Overall Execution of the Article.

GLOBAL ENERGY MANGEMENT
CU Denver Business School

M.S. in Global Energy Management (GEM)

CU Denver Business School's Master of Science in Global Energy Management (GEM) program is a business and leadership degree, offered in a hybrid format that turns today's energy professionals into tomorrow's leaders. The hybrid format includes online coursework and a four-day on-campus weekend held in Denver every three months.

At-A-Glance:

- Credit hours: 36
- 18-month program
- Hybrid format: online and on-campus
- Start terms: Winter and Fall

Graduate with the business acumen of an M.B.A., paired with a future-proof global perspective of the energy industry that spans all sectors. This degree prepares you to advance in your current field or to shift into a new role or sector.

Benefits of the program include:

- Only energy program to offer an Executive in Residence program to give you access to leaders in the industry
- Taught by energy practitioners with extensive experience across a number of industries
- Hybrid format allows you to continue your education while working full-time from anywhere in the world
- Ranked 3rd in the nation for executive energy programs by Hart Publications

Our faculty members average 15 years in the industry. Taught by experts who understand where the trends in energy are headed. Our program model connects business, leadership, and industry expertise.

For more information, visit: https://business.ucdenver.edu/ms/global-energy-management or contact our Global Energy Management team at gem@ucdenver.edu.

EDITORIAL ADVISORY BOARD MEMBER NEWS

Chainalysis, Inc.

B. Salman Banaei, Head of Public Policy at Chainalysis Inc., providing a lecture at a JPMCC Professional Education course.

GCARD Editorial Advisory Board member, **B. Salman Banaei**, has joined Chainalysis Inc. in Washington, D.C. as Head of Public Policy.

Chainalysis creates transparency for a global economy built on blockchains, enabling banks, business, and governments to have a common understanding of how people use cryptocurrency. Chainalysis provides data, software, services, and research to government agencies, exchanges, financial institutions, and insurance and cybersecurity companies in over 60 countries. Their data platform powers investigation, compliance, and risk management tools that have been used to solve some of the world's most high-profile cyber criminal cases and grow consumer access to cryptocurrency safely.

Banaei is also a subject matter expert for Commodities and Derivatives Law at the JPMCC and serves on the U.S. Commodity Futures Trading Commission's Market Risk Advisory Committee.

Columbia University's Center on Global Energy Policy

GCARD Editorial Advisory Board member, **Anne-Sophie Corbeau**, was recently appointed as a Global Research Scholar at the Center on Global Energy Policy at Columbia University's School of International and Public Affairs.

Her most recent article in the *GCARD* covered the Liquefied Natural Gas (LNG) market and is available here**.**

Publication Activity

GCARD Editorial Advisory Board member, **John (Hua) Fan**, Ph.D., has recently been published in the following journals:

- Bianchi, R. J., Fan, J. H., & T. Zhang (2021). "Investable Commodity Premia in China." *Journal of Banking & Finance*, 127, 106127.
  [The *GCARD*'s research digest article version of this paper is available here.]
- Fan, J. H., Mo, D., & T. Zhang (2021). "The 'Necessary Evil' in Chinese Commodity Markets." *Journal of Commodity Markets*, 100186.
  [The GCARD's research digest article version of this paper is available here, which, in turn, won the *GCARD*'s Best Article Award.]
- Fan, J. H., & N. Todorova (2021). "A Note on the Behavior of Chinese Commodity Markets." *Finance Research Letters*, 101424.

Dr. Fan is also a Senior Lecturer in Finance at Griffith Business School (Australia).

Omnium

GCARD Editorial Advisory Board member, **Joseph Eagleeye**, was recently named as an advisor for Omnium, a consulting team composed of mathematicians, data scientists and business professionals with a historic focus on consumer packaged goods (CPG). Eagleeye's recent article on

Omnium (Continued)

how CPG companies should respond to inflation is available here.

Prior to Omnium, Eagleeye was the Chief Financial Officer of Organic Valley, the nation's largest organic, farmer-owned cooperative and one of the world's largest organic consumer brands. As CFO, he oversaw data science, demand planning, supply forecasting, information resources, accounting and finance. While at Organic Valley, he also managed the firm's conventional dairy, fuel and interest rate risk, in addition to creating the data science group. His main contribution was introducing the firm to data-driven solutions and frameworks that fundamentally altered the perception of profitability and client value.

Eagleeye's past co-authored article for the *GCARD* on "Inferring Petroleum-Complex Fundamentals through Price-Relationship Data" is available here. In addition, Eagleeye is the Co-Editor of the bestselling Risk Book (London), "Intelligent Commodity Investing", and the Co-Creator of the Premia Research Bancor Index.

CNBC "Power Lunch"

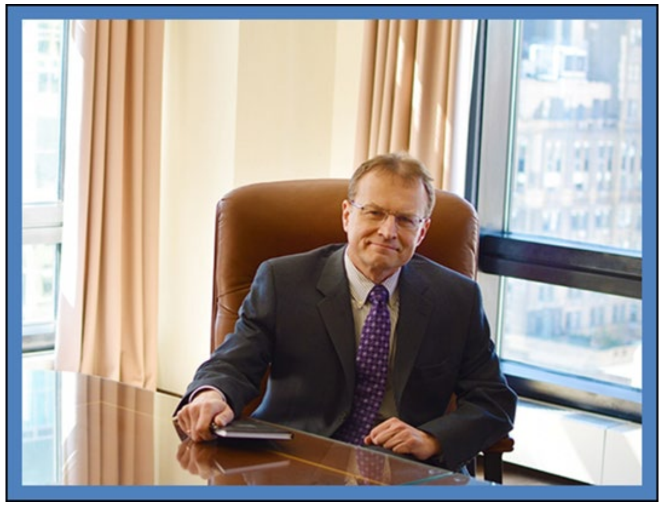
Jodie Gunzberg, CFA, Managing Director at CoinDesk Indexes, during an interview on "Power Lunch."

GCARD Editorial Advisory Board member, **Jodie Gunzberg**, CFA, was interviewed recently on CNBC TV's *Power Lunch* where she discussed the idiosyncrasies of Bitcoin futures contracts. Gunzberg is a Managing Director at CoinDesk Indexes, TradeBlock, and is also a member of the JPMCC's Industry Advisory Council.

CNBC "Power Lunch" (Continued)

Gunzberg was interviewed earlier this year in the *GCARD* on education- and commodity-based themes.

Oxford Institute of Energy Studies



Dr. Ilia Bouchouev, Ph.D., is the Managing Partner at Pentathlon Investments. He is a frequent commentator on commodities on Twitter @IliaBouchouev and on LinkedIn.

GCARD Editorial Advisory Board member, **Ilia Bouchouev**, Ph.D., has published an article for the Oxford Institute of Energy Studies (OIES) on the question, "Is the Oil Price-Inflation Relationship Transitory?" Dr. Bouchouev argues that the market has an answer. His latest article is available here, which in turn cites a recent *GCARD* article on the portfolio hedging properties of crude oil exposure.

Dr. Bouchouev is also an Adjunct Professor at New York University's Courant Institute of Mathematical Sciences as well as a Research Associate at OIES. In addition, he is the former president of Koch Global Partners where he managed the global derivatives trading business for over twenty years.

Dr. Bouchouev co-authored an article on "Oil Risk Premia under Changing Regimes" in a previous edition of the *GCARD* and has co-authored an article in the current edition of the *GCARD* on "The Smile of the Volatility Risk Premia" in the oil markets.

Top Ten Wealth Manager

Hilary Till is the Solich Scholar at the J.P. Morgan Center for Commodities (JPMCC) and is a member of both the JPMCC's Industry Advisory Council and Research Council.

The *GCARD*'s Editor, **Hilary Till**, recently joined a top 10 U.S. wealth manager as Head of Portfolio Risk Analysis. Further information on this appointment is here.

Two of her past *GCARD* articles were cited recently. A University of Illinois paper on "the weather risk premium in new-crop corn futures prices" cited Till's *GCARD* article on weather fear premia trades. In addition, the CAIA Association's "Portfolio for the Future" excerpted from Till's July 2021 *GCARD* Newsletter article on commodities, crude oil, and diversified portfolios.

In addition, one of Till's papers for the EDHEC-Risk Institute (France, Singapore) on the factors that determine the success of a futures contract was cited in a Yale School of Management working paper on "The Commodity Futures Risk Premium: 1871-2018." Till is also a Research Associate at the EDHEC-Risk Institute.

Till was also previously cited in the *Wall Street Journal* on the potential role of gold in a strategic asset allocation.

Wall Street Journal

Both **David Jacks**, Ph.D., a professor at Singapore's Yale-NUS College, and **Daniel Jerrett**, Ph.D., Chief Investment Officer at Stategy Capital LP, were cited in

Wall Street Journal (Continued)

a Wall Street Journal article on commodity super cycles.

Dr. Jacks is a member of the *GCARD*'s Editorial Advisory Board; and Dr. Jerrett is a member of the JPMCC's Industry Advisory Council. Dr. Jerrettt also lectures for the JPMCC and the CU Denver Global Energy Management program. Both researchers also wrote articles, which analyze long-term commodity price data, for the Summer 2021 edition of the *GCARD*.

In addition, Dr. Jerrett is interviewed in the current issue of the *GCARD*.

Journal of Futures Markets

A paper co-written by *GCARD* Editorial Advisory Board member, **Isabel Figuerola-Ferretti**, Ph.D., Assistant Professor in Finance, ICAI-ICADE, Universidad Pontificia de Comillas (Spain), was recently published in the *Journal of Futures Markets*. The paper covers the accuracy of oil price forecasts by analysts and is available here.

Professor Isabel Figuerola-Ferretti, Ph.D., Universidad Pontificia de Comillas (Madrid), presenting on the statistical properties of crude oil prices at a European Financial Management Association conference.

Journal of Futures Markets (Continued)

Dr. Figuerola-Ferretti had previously contributed an article to the *GCARD* on:

"Futures Trading Opportunities: Fundamentally-Oriented and Convergence Trading."

EDOC Acquisition Corp.

Kaifeng (Kevin) Chen, Ph.D., with the *GCARD*'s Editor, Hilary Till, at a J.P. Morgan Center for Commodities international commodities symposium. Dr. Chen had presented at the symposium on China's economy.

GCARD Editorial Advisory Board member, **Kaifeng (Kevin) Chen**, Ph.D., was named as Chairman and CEO of EDOC Acquisition Corp. EDOC Acquisition Corp. is a blank check company organized for the purpose of effecting a merger, share exchange, asset acquisition, share purchase, recapitalization, reorganization, or other similar business combination with one or more businesses or entities.

It intends to focus on businesses primarily operating in the healthcare sector in North America and Asia-Pacific.

Dr. Chen is also the Chief Economist for Horizon Financial and an Adjunct Assistant Professor at New York University's Center for Global Affairs.

EDOC Acquisition Corp. (Continued)

Dr. Chen's last co-authored article for the *GCARD* summarized a past JPMCC international commodities symposium in which he had been a panelist.

Oktoberfest Fall Mining Showcase

The JPMCC's Executive Director, **Thomas Brady**, Ph.D., was the keynote speaker for Red Cloud Financial Services Inc.'s Oktoberfest Fall Mining Showcase. Dr. Brady is also a Managing Director at Capitalight Research, Canada and was the former Chief Economist at Newmont Mining.

Dr. Brady is also a member of the *GCARD*'s Editorial Advisory Board, and he discusses the importance of a commodity education in the current issue of the *GCARD*.

Professional Education

Partnership with Erasmus and Singapore Management Universities and the J.P. Morgan Center for Commodities (JPMCC)

Executive Programme: Leadership in Commodity Trade and Supply Networks

The "Leadership in Commodity Trade and Supply Networks" programme is unique in the world. It is the only programme that is designed for business executives, and which takes place across three continents. The programme is offered by Erasmus University, in partnership with Singapore Management University and the J.P. Morgan Center for Commodities. It is interdisciplinary and focuses on developing leadership skills and strategic thinking. The programme is both theoretically informed and hands-on with real world cases so as to provide a true learning experience across three continents.

Leadership in Commodity Trade & Supply Networks

- 6-month program
- ~ €23,000 (~$27,000) with discounts available for companies with multiple participants
- Professionals with 3-to-8 years of experience in the trading and shipping of physical commodities or affiliated industries.
- 4 commodity-based learning modules: Risk and Compliance, Geopolitics, Technology & Innovation, and Sustainability

Schedule

The next offering will begin in January 2022 with in-person sessions in Rotterdam. Participants will then participate in classes at the JPMCC in Denver (March) followed by a week in Singapore later in May.

- Introduction — January 19 – 21, 2022
- Europe — January 24 – 28, 2022
- North America — March 28 – April 1, 2022
- Asia — May 9 – 13, 2022

The course is presented by industry practitioners, business leaders and experts as well as by faculty from the affiliated business schools.

Full details are included in the executive programme's brochure and on the programme's website.

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

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 in association with Premia Education, Inc.

The JPMCC is the first center of its kind focused on a broad range of commodities, including agriculture, energy, and mining. Established in 2012, this innovative center provides educational programs and supports research in commodities markets, regulation, trading, investing, and risk management. The JPMCC's Executive Director is Dr. Thomas Brady, Ph.D.

Subscriptions to the *Global Commodities Applied Research Digest* are complimentary at jpmcc-gcard.com/subscribe.

The Winter 2021 *GCARD* cover image is cropped from the following artwork, whose complete image is above: Poster for the London & North Eastern Railway (LNER) Bennie Railplane system. Public Domain. Accessed at: atlasobscura.com/articles/george-bennie-railplane-1929-1930-glasgow, "The 1929 Plane-Train Hybrid That Almost Was," by Michael Waters, June 26, 2017. Originally Published: 1929. Original Artist: WCN/McCorquodale Studio. Wording: "Erected over LNER line—Milngavie Station (near Glasgow). Swift, Safe, Sure. The George Bennie Railplane System of Transport."

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