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

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

WINTER 2018

Supported by a generous grant from

CME GROUP FOUNDATION

Business School
UNIVERSITY OF COLORADO DENVER

GLOBAL COMMODITIES APPLIED RESEARCH DIGEST
Vol. 3, No. 2: Winter 2018
Index of Articles

Research Director Report	**Page**
Jian Yang, Ph.D., CFA	**11**
Contributing Editor's Letter	**Page**
Hilary Till	**23**
Research Council Corner	**Page**
ECONOMIST'S EDGE **Four Ideas to Consider When Analyzing Long-Term Prospects for Oil and Natural Gas** *Bluford Putnam, Ph.D.*	**31**
Shaping and Hedging Renewable Power Purchase Agreements *Brock Mosovsky, Ph.D. and Lance Titus*	**42**
The Superclasses of Assets Revisited *Robert Greer*	**62**
Research Digest Articles	**Page**
Just a One-Trick Pony? An Analysis of CTA Risk and Return *As Summarized by Ana-Maria Fuertes, Ph.D.*	**68**
Child Mortality, Commodity Price Volatility and the Resource Curse *As Summarized by Ana-Maria Fuertes, Ph.D.*	**73**
Contributing Editor's Section	**Page**
An Additional Aspect of Whether Futures Contracts Succeed: The Nature of Governmental Intervention *Hilary Till*	**77**
Industry Commentaries	**Page**
The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy *Adam Sieminski, CFA*	**88**
What are the Factors that are Impacting Global Oil Prices? *Robert McNally*	**92**
The New Geopolitics of Natural Gas *Agnia Grigas, Ph.D.*	**103**
Special Feature: Cryptoassets and Blockchain	**Page**
Cryptocurrencies, Bitcoin and Blockchain: An Educational Piece on How They Work *Mark Keenan, Michael Haigh, Ph.D., David Schenck and Klaus Baader*	**SF1**
How Futures Trading Changed Bitcoin Prices *Galina Hale, Ph.D., Arvind Krishnamurthy, Ph.D., Marianna Kudlyak, Ph.D., and Patrick Shultz*	**SF36**
Blockchain for Physical Commodity Markets - A Realist's Perspective *Julie Lerner*	**SF43**
Interview with Don Wilson, CEO of DRW; and Co-Founder and Board Member, Digital Asset Holdings	**SF48**

TABLE OF CONTENTS
Vol. 3, No. 2: Winter 2018

Introduction

Introduction 7

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

Research Director Report

Update from the Research Director of the J.P. Morgan Center for Commodities 11

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

This issue's Research Director Report covers both (a) the highlights of the JPMCC's 2nd annual international commodities symposium and (b) additional international outreach activities by the JPMCC's research director. The JPMCC's next high-profile symposium, featuring global commodity thought leaders, is scheduled for August 12 and August 13, 2019 in Denver.

Advisory Council

Advisory Council 18

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

Research Council

Research Council 20

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

Editorial Advisory Board

Editorial Advisory Board 22

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

Contributing Editor's Letter

Contributing Editor's Letter **23**

By Hilary Till, Solich Scholar, J.P. Morgan Center for Commodities, University of Colorado Denver Business School; and Principal, Premia Research LLC

The sixth issue of the *Global Commodities Applied Research Digest* includes, amongst its articles, such energy themes as (a) the importance of crude oil swing producers and spare capacity; (b) the dramatic changes in the liquefied natural gas markets; and (c) the analysis of renewable power purchase agreements. Along with these themes, we are including an educational special feature on cryptoassets and blockchain.

Research Council Corner

ECONOMIST'S EDGE

Four Ideas to Consider When Analyzing Long-Term Prospects for Oil and Natural Gas **31**

By Bluford Putnam, Ph.D., Chief Economist, CME Group and Member of the JPMCC's Research Council

Periodically, analysts and forecasters benefit from spending some time thinking about what might be the most disruptive developments that could materially change the way we analyze markets over a long-term horizon. In this research, we provide a perspective on the developments that may shape oil and natural gas markets as they evolve during the 2020s.

Shaping and Hedging Renewable Power Purchase Agreements **42**

By Brock Mosovsky, Ph.D., Director of Operations and Analytics, cQuant.io and Lance Titus, Managing Director, Uniper Global Commodities and Member of both the JPMCC's Research Council and the GCARD's Editorial Advisory Board

This article is the second in a two-part series on the valuation and risk assessment of renewable Power Purchase Agreements (PPAs). The present paper outlines methodologies for shaping and hedging renewable PPAs, and we discuss the benefits of each of these strategies from both the buyer and seller perspectives.

The Superclasses of Assets Revisited **62**

By Robert Greer, Scholar-in-Residence, J.P. Morgan Center for Commodities (JPMCC), University of Colorado Denver Business School and Member of the JPMCC's Research Council

The three "super asset classes" are Capital Assets, Consumable/Transformable Assets, and Store of Value Assets. This framework can help asset allocators consider the diversification of risk factors that produces more effective portfolios. This framework also contributes to the understanding of how commodity investing fits into comprehensive portfolios.

Research Digest Articles

Just a One-Trick Pony? An Analysis of CTA Risk and Return **68**

As summarized by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics, Cass Business School, City, University of London, U.K. and Member of the GCARD's Editorial Advisory Board

This digest article summarizes a co-written paper by the following four Cork University Business School, University College Cork, Ireland researchers: Jason Foran, Ph.D.; Mark Hutchinson, Ph.D.; David McCarthy, Ph.D.; and John O'Brien, Ph.D. Their article examines the ability of alternative-risk-premia products to capture the returns of the commodity trading advisor (CTA) sector. The paper's empirical analysis indicates that CTAs have return series that cannot be easily replicated through factor investing.

Child Mortality, Commodity Price Volatility and the Resource Curse **73**

As summarized by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics, Cass Business School, City, University of London, U.K. and Member of the GCARD's Editorial Advisory Board

This digest article summarizes a research paper by the following three co-authors: Yousef Makhlouf, Ph.D., College of Business Law and Social Sciences, Nottingham Trent University, U.K.; Neil Kellard, Ph.D., Essex Business School and Essex Finance Centre, University of Essex, U.K.; and Dmitri Vinogradov, Ph.D., Adam Smith Business School, University of Glasgow, U.K. Their paper empirically investigates the impact of commodity price movements on child mortality in low and lower-middle income countries. They find that commodity terms-of-trade volatility increases child mortality in highly commodity-dependent importers. They also find that the presence of sound institutions (proxied by democracy) mitigates the harmful impact of commodity price volatility.

Contributing Editor's Section

An Additional Aspect of Whether Futures Contracts Succeed: The Nature of Governmental Intervention **77**

By Hilary Till, Solich Scholar, J.P. Morgan Center for Commodities, University of Colorado Denver Business School; and Principal, Premia Research LLC

The history of futures regulations reveals four features in determining whether a futures contract can succeed: (a) a contract must have a convincing economic rationale; (b) it is helpful if contracts are viewed as being in the national interest; (c) competition requires regulatory parity among exchanges; and (d) markets can survive even draconian interventions so long as they are short-term. This paper is excerpted from a seminar that was provided by the author for staff at the Shanghai Futures Exchange.

Industry Commentaries

The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy **88**

By Adam Sieminski, CFA, President, King Abdullah Petroleum Studies and Research Center (KAPSARC), Saudi Arabia

This commentary is based on a KAPSARC research project that resulted in the April 2018 publication of the paper, "OPEC's Impact on Oil Price Volatility: The Role of
(Continued on next page.)

Industry Commentaries
(Continued)

Spare Capacity," in the *Energy Journal*. This study finds that OPEC's spare capacity reduces oil price volatility and generates between $170 and $200 billion of annual economic benefits for the global economy.

What are the Factors that are Impacting Global Oil Prices? 92
By Robert McNally, Founder and President, Rapidan Energy Group

This paper argues that we are in a new era marked by boom-and-bust oil price swings. Spare capacity has been very tight. This can pose a risk of oil price spikes eventually occurring, given the large number of actual and threatened disruptions present in the oil market.

The New Geopolitics of Natural Gas 103
By Agnia Grigas, Ph.D., Nonresident Senior Fellow, Atlantic Council and Board Member, LITGAS

This article reviews how, over the last decade, the transformation of the natural gas markets has ushered in a shift of global geopolitics by the changing relationships between natural gas exporting, importing, and transit states. The article draws from the author's book of the same title and explores how this energy revolution was driven by the shale boom, the rise of the liquefied natural gas trade, the rise in interconnective gas infrastructure, and growing global demand for natural gas as a cleaner fossil fuel.

Editorial Advisory Board (EAB) Member News

Editorial Advisory Board (EAB) Member News 111

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

Professional Society Partnership

The Chartered Alternative Investment Analyst (CAIA) Association 113

We are pleased to announce that the Chartered Alternative Investment Analyst (CAIA) Association is joining the International Association for Quantitative Finance as a new professional group partner of the *Global Commodities Applied Research Digest*. The CAIA Association, in turn, is the world leader in alternative investment education and is known for the CAIA Charter. Earning the CAIA Charter is the gateway to becoming a member of the CAIA Association, a global network of over 9,000 alternative investment leaders. CAIA also offers the Fundamentals of Alternative Investments Certificate Program®. For more information, please visit www.caia.org. The Contributing Editor of the *GCARD* is a member of CAIA Chicago's Steering Committee.

SPECIAL FEATURE: Cryptoassets and Blockchain

Cryptocurrencies, Bitcoin and Blockchain: An Educational Piece on How They Work SF1

By Mark Keenan, Managing Director, Global Commodities Strategist and Head of Research for Asia Pacific, Société Générale Corporate & Investment Bank (Singapore) and Member of the GCARD's Editorial Advisory Board; Michael Haigh, Ph.D., Managing Director and Global Head of Commodities Research, Société Générale (U.S.); David Schenck, Commodities Analyst, Société Générale (U.K.); and Klaus Baader, Global Chief Economist, Société Générale (U.K.)

This educational paper is divided into three parts. The first part briefly describes the nascent cryptocurrency market, focusing on the bitcoin system. The second part examines bitcoin's price behavior from a quantitative perspective, highlighting the low correlation of bitcoin and other cryptocurrencies to other traditional asset classes. The final section provides a complete overview, including definitions and explanations of all the processes and mechanics behind bitcoin and the blockchain.

How Futures Trading Changed Bitcoin Prices SF36

By Galina Hale, Ph.D., Research Advisor, Federal Reserve Bank of San Francisco; Arvind Krishnamurthy, Ph.D., The John S. Osterweis Professor of Finance, Stanford Graduate School of Business; Marianna Kudlyak, Ph.D., Research Advisor, Federal Reserve Bank of San Francisco; and Patrick Shultz, Doctoral Candidate, Wharton School, University of Pennsylvania and Former Research Associate, Federal Reserve Bank of San Francisco

Bitcon's peak price coincided with the introduction of bitcoin futures trading on the Chicago Mercantile Exchange. The rapid run-up and subsequent fall in the price after the introduction of futures does not appear to be a coincidence. Rather, it is consistent with trading behavior that typically accompanies the introduction of futures markets for an asset.

Blockchain for Physical Commodity Markets - A Realist's Perspective SF43

By Julie Lerner, Chief Executive Officer, PanXchange

Regarding the physical commodity markets, this article recommends that blockchain providers consider the following approach. Start with the points of highest pain, like streamlining cumbersome bills of lading. Find a reliable blockchain provider or neutral third party that can understand the idiosyncrasies of the physical supply chain and both the opportunities and limitations of the technology. Coordinate the piloting and the implementation with the industry's largest players. Blockchain is ultimately an opt-in solution. Build it to their specifications, and they will come, predicts the author.

Interview with Don Wilson, CEO of DRW; and Co-Founder and Board Member, Digital Asset Holdings SF48

Mr. Don R. Wilson is the CEO of the principal trading firm, DRW. He is also a co-founder and board member of Digital Asset Holdings, which leverages distributed ledger technology to improve the settlement of financial instruments. Based on his extensive business ventures, Mr. Wilson discusses his views on both cryptoassets and blockchain.

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. The University of Colorado Denver Business School is led by Dr. Rohan Christie-David, Ph.D., Dean and Professor of Finance.

Dr. Rohan Christie-David, Ph.D., Dean of the University of Colorado Denver Business School and Professor of Finance, welcomes participants to the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018.

The JPMCC's Research Director is Dr. Jian Yang, Ph.D., CFA, who is also the J.P. Morgan Endowed Research Chair and Professor of Finance and Risk Management at the University of Colorado Denver Business School.

Dr. Jian Yang, Ph.D., CFA**,** J.P. Morgan Endowed Research Chair, JPMCC Research Director, and Professor of Finance and Risk Management at the University of Colorado Denver Business School, delivered the keynote speech at "The First Workshop on the Chinese Oil Futures and Energy Markets," which took place on June 26, 2018 at Xiamen University in China.

The Director of the JPMCC is Dr. Yosef Bonaparte, Ph.D., who is also an Associate Professor of Finance at the University of Colorado Denver Business School. Dr. Bonaparte is responsible for the day-to-day operations of the JPMCC, including its professional activities.

Dr. Yosef Bonaparte (standing), Ph.D., Director of the J.P. Morgan Center for Commodities and Associate Professor of Finance at the University of Colorado Denver Business School, was the academic discussant at the JPMCC's Research Council panel on "Fracking, China, and the Geopolitics of Oil" on December 4, 2015. Also participating in the panel were the following JPMCC Research Council members from left-to-right: Dr. James Hamilton (presenter), Ph.D., Professor of Economics at the University of California, San Diego; Dr. Bluford Putnam (practitioner discussant), Ph.D., Chief Economist of the CME Group; and Dr. Margaret Slade (moderator), Ph.D., Professor Emeritus of Economics at the Vancouver School of Economics, University of British Columbia. Dr. Hamilton and Dr. Slade are Co-Chairs of the JPMCC's Research Council with Dr. Hamilton also serving as the JPMCC's first Distinguished Visiting Fellow.

The JPMCC's Program Manager, in turn, is Mr. Matthew Fleming.

The aim of the *GCARD* is to serve the JPMCC's applied research mission by informing commodity industry practitioners on innovative research that will either directly impact their businesses or will impact public policy in the near future. The digest has been made possible by a generous grant from the CME Group Foundation and is published twice per year. Periodic updates on *GCARD*-related activities can be found at https://www.linkedin.com/company/jpmcc-gcard/.

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

The *GCARD*'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.

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

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

Dr. Jeffrey Frankel, Ph.D., James W. Harpel Professor of Capital Formation and Growth in the Kennedy School at Harvard University, provided the keynote address during the second day of the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018. Dr. Frankel's keynote presentation was on the "Macroeconomic Determinants of International Commodity Prices." Dr. Frankel is also a member of the JPMCC's Research Council.

This issue's Research Director Report will cover both (a) the highlights of the JPMCC's 2nd annual international symposium and (b) additional international outreach activities by the JPMCC's research director. In addition, we will continue coverage of the symposium in future issues of the *GCARD*, which will include articles from the 2018 symposium presenters.

Highlights of the JPMCC's 2nd International Commodities Symposium

Building on the success of the previous year's inaugural conference, this year's symposium continued with the theme of "New Directions in Commodities Research." The conference program included 18 competitively selected, high-quality papers, all of which had both academic rigor and practical relevance. Like last year, we also included an industry panel with three distinguished practitioners, whom in turn discussed both trends and structural changes in the commodity markets. And new to this year, we added a session that featured "Commodity Research in China."

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

Among the many top commodities scholars at the symposium, we were very fortunate to have Dr. Jeffrey Frankel, Ph.D., deliver a keynote speech on the topic of "Macroeconomic Determinants of International Commodity Prices," which is very timely, given the expected further increases in U.S. interest rates. Dr. Frankel is the James W. Harpel Professor of Capital Formation and Growth at Harvard

University's Kennedy School and is a former Chief Economist in the U.S. President's Council of Economic Advisers. In addition, Dr. Robert Webb, Ph.D., provided a keynote address on "What Drives Success in Derivatives Markets?", a topic of renewed interest, given the expansion of futures trading and innovation in China. Dr. Webb is a Research Professor in Finance at the University of Virginia and also serves as the Editor of the *Journal of Futures Markets*, a leading academic journal focusing on derivative securities and markets. We are honored that both Dr. Frankel and Dr. Webb recently joined the JPMCC's Research Council.

Dr. James Hamilton, Ph.D., chaired the symposium's Best Paper Award Selection Committee. Dr. Hamilton is a Professor of Economics at the University of California, San Diego and is also Co-Chair of the JPMCC's Research Council in addition to serving as the JPMCC's first Distinguished Visiting Fellow. The Best Paper was awarded to both Dr. Andrei Kirilenko, Ph.D., of Imperial College Business School and Ms. Anna Kruglova of the University of Washington.

The winners of the Best Paper Award at the JPMCC's 2nd International Commodity Symposium were **Ms. Anna Kruglova**, Ph.D. student at the University of Washington, and **Dr. Andrei Kirilenko**, Ph.D., Senior Research Fellow at Imperial College Business School, who are flanked by **Dr. James Hamilton** (left), Ph.D., Professor of Economics at the University of California, San Diego and **Dr. Jian Yang** (right), Ph.D., CFA, J.P. Morgan Endowed Research Chair at the University of Colorado Denver Business School.

Dr. Kirilenko is the Director of the Centre for Global Finance and Technology at Imperial College Business School and is a past Chief Economist of the U.S. Commodity Futures Trading Commission. Kirilenko and Kruglova's winning paper was on "Speculative Floating Oil." In addition, Dr. Lutz Kilian, Ph.D., was selected to receive the Best Discussant Award. Dr. Kilian is a Professor of Economics at the University of Michigan at Ann Arbor and also serves on the JPMCC's Research Council. Congratulations to Dr. Kirilenko, Ms. Kruglova, and to Dr. Kilian!

Building on the visibility from last year's conference, we had substantially more registrants as compared to 2017's inaugural conference, contradicting the notion that commodities are not a hot area of research. Academics from the following seven countries, the U.S., China, U.K., Germany, Canada, Australia, and Poland, contributed to the conference program with first-time participation from colleagues based in Australia, China, and Germany. We were pleased with the attendance from additional countries such as Argentina. The symposium drew extensive participation from top institutions from around the world (e.g., Harvard, Yale, Cornell, UC-Berkeley, Imperial College London, University of British Columbia, and Peking University.) As can be surmised from this list, this year's conference included participants from Ivy League institutions. In addition, the symposium included presentations from researchers at policy-making institutions (e.g., the Federal Reserve Board, Bank of Canada, and the U.S. Energy Information Administration) as well as from leading industry practitioners (e.g., the chief economists from the CME Group, CoBank, and Newmont Mining.)

At this year's conference, we made a number of changes to further improve the symposium. (1) We created the "Applied Commodity Research Leaders Forum" to showcase research insights from industry. We were very fortunate to have both Dr. Bluford Putnam, Ph.D., Managing Director and Chief Economist of the CME Group (and JPMCC Research Council Member) and Dr. Terry Barr, Ph.D., Senior Director, Knowledge Exchange Division of CoBank, as our industry forum speakers. (2) For the first time, we will have a special issue for the symposium, sponsored by the *Journal of Futures Markets*, which will add to the academic reputation of the symposium. (3) We organized both domestic and international media coverage of the symposium, which has increased the visibility of the symposium and the brand awareness of the JPMCC to the business community. Thus far, there are five media articles covering the symposium already published in both English and Chinese, including in *Financial Advisor Magazine* (Reiner, 2018), *Futures Daily*, *Yicai,* and in *Yicai Global* (Hou, 2018) with another article scheduled to be published in *China Futures Magazine*. Accordingly, the viewpoints of many of the presenters at the JPMCC symposium were concisely summarized and shared to industry professionals internationally, and the acronym, JPMCC, and the symposium were featured in these media articles. In addition, *Yicai*, published by China's leading financial news conglomerate, the Shanghai Media Group (second only to state-owned, China Central TV), completed exclusive interviews with three distinguished speakers attending the symposium, and have already published two of them with plans to publish the remaining one in due course. Thus, we expect eight media articles in total featuring the symposium.

Our symposium's success is likely due to how relevant it is to the commodities space, as the conference brings together global thought leaders and prominent stakeholders to discuss critical thinking and new research related to commodities. Commodities matter to every kind of business. On the other hand, commodity markets are complex and constantly evolving, and thus there is generally a lack of understanding about these markets. With the support of many top commodities scholars attending the conference, the 2018 JPMCC symposium provided a very useful platform for knowledge exchange in the commodities space.

Participants reported to us that the conference included a good mix of academics and practitioners that allowed unique and meaningful exchange of ideas among them. In addition, the conference was judged to be about the right size for close interactions among participants. Lastly, and of course not least, the JPMCC was blessed to have many top commodities research scholars (from both academia and industry) in attendance at the symposium.

Dr. Thomas K. Lee (left), Ph.D., Senior Economist in the Office of Energy Markets and Financial Analysis at the U.S. Energy Information Administration, confers with **Dr. Lutz Kilian** (right), Ph.D., University of Michigan at Ann Arbor, Professor of Economics, during the JPMCC's 2nd International Commodities Symposium, which was held on August 14 and August 15, 2018 at the University of Colorado Denver Business School. Dr. Lee is a member of the *GCARD*'s Editorial Advisory Board while Dr. Kilian is a member of the JPMCC's Research Council.

Additional Outreach Activities by the JPMCC Research Director

The success of this year's symposium also benefits from earlier research activities and media exposure of the JPMCC. During the past academic year (September 2017 through September 2018), the JPMCC Research Director entertained numerous media interviews about commodities (particularly on China's new oil futures contracts), which resulted in about 60 media articles in several dozen countries, written in multiple languages (e.g., English, Chinese, Italian, and in Indonesian.) Accordingly, the JPMCC was featured globally in many prominent media outlets such as in *Bloomberg*, *Forbes*, *China Daily* (U.S. edition), *China Daily European Weekly* (U.K.), *China Daily African Weekly* (Kenya), *World Finance* magazine (U.K.), *Australian Financial Review*, *The Business Times* (Singapore), and on RT, the Russian international television network. The JPMCC was also featured in the following major Chinese-language media outlets (among others): *Economic Daily*, *China National Radio*, and *China Securities Journal.* Of note is that two of these media articles in Chinese, featuring the JPMCC Research Director, were posted on the official websites of the Chinese Central Government and its National Energy Administration (in addition to the official websites of other national government agencies and many provincial governments in China.)

The JPMCC Research Director also delivered a keynote speech based on an ongoing research project at the Workshop on the Chinese Oil Futures and Energy Markets at Xiamen University in China on June 26, 2018, which was the first-ever academic workshop on this topic. The event attracted national media attention in China, resulting in (at least) 6 media articles in Chinese that featured the research findings of the JPMCC Research Director. During the conference, the research director worked closely with the workshop's organizer, which will be helpful as we co-organize an international workshop in China in the near future. These outreach activities have been very helpful in promoting the reputation of the JPMCC in China, which has become the world's largest consumer of commodities.

Conclusion: Next Year's International Commodities Symposium

Based on the feedback and suggestions that we received from many participants during the August 2018 JPMCC international commodities symposium, we look forward to delivering an even higher quality program at our next symposium, which is scheduled for August 12 and August 13, 2019 in Denver. We hope to see you there!

Jian Yang, Ph.D., CFA

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

References

Hou, X., 2018, "Commodity Market Must Pay Attention to Event Risks, JPMCC Symposium Experts Say," *Yicai Global*, September 3. Accessed via website:
https://www.yicaiglobal.com/news/commodity-market-must-pay-attention-event-risks-jpmcc-symposium-experts-say
on October 15, 2018.

Reiner, E., 2018, "Oil-Price Shocks Have Delayed Reaction on Stock Prices, Researchers Say," *Financial Advisor Magazine*, August 20. Accessed via website:
https://www.fa-mag.com/news/oil-price-shocks-have-delayed-reaction-on-stock-prices--researchers-say-40353.html?print
on October 15, 2018.

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

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

Dr. Thomas Brady, Ph.D., Chief Economist of Newmont Mining, presenting on "Investor Preferences in Gold Markets" during the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018. Dr. Brady is a member of the JPMCC's Advisory Council. In addition, he is also a member of both the JPMCC's Research Council and the *GCARD*'s Editorial Advisory Board.

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

Corporate Members of the J.P. Morgan Center for Commodities (JPMCC) Advisory Council

Ardent Mills LLC	***J.P. Morgan (Co-Chair)***
Blacklight Research, LLC (Co-Chair)	***Newmont Mining Corporation***
CME Group	***Razor Commodity Advisors, LLC***
CoBank	***Robert Bosch GmbH***
Encana	***Trinidad Benham Corp.***
Fonterra Co-Operative Group Limited	***Uniper Global Commodities***
FourPoint Energy, LLC	***Xcel Energy***

Mr. Colin Fenton (right-hand side of photo)**,** Managing Partner and Head of Research, Blacklight Research LLC, poses a question during the JPMCC's Advisory Council Meeting held on March 8, 2018. Mr. Fenton is the Co-Chair of the JPMCC's Advisory Council. From left-to-right of the photo are also Mr. Lance Titus, Managing Director, Uniper Global Commodities and JPMCC Advisory Council member and Ms. Hilary Till, Solich Scholar, JPMCC and Contributing Editor of the *GCARD*.

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

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

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

J.P. Morgan Center for Commodities Research Council Members

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

Dr. Sueann AMBRON *J.P. Morgan Center for Commodities*	**Matthew MOST** *Encana*
Thorvin ANDERSON, CFA *Razor Commodity Advisors, LLC*	**Nikos NOMIKOS, Ph.D.** *Cass Business School, City, University of London (U.K.)*
Marcelle ARAK, Ph.D. *University of Colorado Denver Business School*	**Don PEARSON** *Ardent Mills*
Thomas BRADY, Ph.D. *Newmont Mining Corporation*	**Robert PINDYCK, Ph.D.** *Massachusetts Institute of Technology*
Colin CARTER, Ph.D. **Co-Chair, JPMCC Research Council** *University of California, Davis*	**Craig PIRRONG, Ph.D.** *University of Houston*
Graham DAVIS, Ph.D. *Colorado School of Mines*	**Bluford PUTNAM, Ph.D.** *CME Group*
Nancy DeVORE *DHF Team, LLC*	**Forest REINHARDT, Ph.D.** *Harvard University*
Colin FENTON *Blacklight Research, LLC*	**Michel ROBE, Ph.D.** *University of Illinois at Urbana-Champaign*
Jeffrey FRANKEL, Ph.D. *Harvard University*	**Ehud RONN, Ph.D.** *University of Texas at Austin*
Robert GRAY, CFA *Resource Capital Funds*	**Geert ROUWENHORST, Ph.D.** *Yale University*
Robert GREER *J.P. Morgan Center for Commodities*	**Bryce SCHNEIDER** *Xcel Energy*
James HAMILTON, Ph.D. **Co-Chair, JPMCC Research Council, and Distinguished Visiting Fellow at the JPMCC** *University of California, San Diego*	**Margaret SLADE, Ph.D.** **Co-Chair, JPMCC Research Council** *University of British Columbia*
Dave HAMMOND, Ph.D. *Hammond International Group*	**Sven STREITMAYER** *Robert Bosch GmbH (Germany)*
Geoff HOULTON *Anadarko Petroleum Corporation*	**Hilary TILL** *J.P. Morgan Center for Commodities*
Scott IRWIN, Ph.D. *University of Illinois at Urbana-Champaign*	**Lance TITUS** *Uniper Global Commodities*
Vince KAMINSKI, Ph.D. *Rice University*	**Robert VIGFUSSON, Ph.D.** *Board of Governors of the Federal Reserve System*
Lutz KILIAN, Ph.D. *University of Michigan at Ann Arbor*	**Robert WEBB, Ph.D.** *University of Virginia*
Dan KOWALSKI *CoBank*	**Brian WRIGHT, Ph.D.** *University of California, Berkeley*
Benjamin LEE, Ph.D. *National Renewable Energy Laboratory*	**Wei XIONG, Ph.D.** *Princeton University*
Peter McCALLUM *Bunge Limited*	

EDITORIAL ADVISORY BOARD
OF THE
GLOBAL COMMODITIES APPLIED RESEARCH DIGEST

Contributing Editor's Letter

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

Ms. Hilary Till, the Contributing Editor of the *Global Commodities Applied Research Digest (GCARD)*, with Mr. Leo Melamed, Chairman Emeritus of the CME Group, on October 12, 2018. Mr. Melamed will be interviewed in a forthcoming issue of the *GCARD* on financial and technological innovation, past and present. Consistent with the theme of innovation, this issue of the *GCARD* includes a special feature on cryptoassets and blockchain.

Dear Reader,

Welcome to the sixth issue of the *Global Commodities Applied Research Digest*. We are grateful that members of both the JPMCC's Research Council and the *GCARD*'s Editorial Advisory Board have continued to lend their expertise to the Winter 2018 issue of the *GCARD*. And we are thankful that additional commodity thought-leaders have begun contributing to the *GCARD* as well.

This issue includes articles that cover energy themes that have been past favorites of the *GCARD* such as (a) the importance of crude oil swing producers and spare capacity; (b) the dramatic changes in the liquefied natural gas markets; and (c) the analysis of renewable power purchase agreements. Along with these familiar themes, we are proud to announce a completely new section: an educational special feature on cryptoassets and blockchain. We anticipate that we will continue addressing this innovative area in future issues of the *GCARD*. Now before describing each of the current issue's articles, we need to note that two sets of congratulations are very much in order.

Congratulatory Notes

Kudos must first go to Dr. Jian Yang, the JPMCC's Research Director and J.P. Morgan Endowed Research Chair, for organizing a very successful conference of global commodity experts during the JPMCC's 2nd International Commodity Symposium in August. Dr. Yang is also a Professor of Finance and Risk Management at the University of Colorado Denver Business School. Observed Dr. Andrei Kirilenko of the Imperial College Business School (U.K.) in Linares (2018): "I have been in this field for a long time and can tell you the quality of [the conference's] papers and presentations and presenters is world-class."

In addition, the *GCARD* team is delighted to welcome Dr. Yosef Bonaparte as the newly named Director of the JPMCC. Dr. Bonaparte is also an Associate Professor of Finance at the University of Colorado Denver Business School. Dr. Rohan Christie-David, the Dean of the Business School, noted: "I am looking forward to seeing the Center go from strength to strength" with Dr. Bonaparte (as director, responsible for the day-to-day operations of the Center) and with Dr. Yang (as research director of the Center).

The Winter 2018 Issue's Content

This issue of the *GCARD* is divided into the following six sections: (1) the Research Council Corner; (2) the Research Digest Articles section; (3) the Contributing Editor's Section; (4) the Industry Commentaries section; (5) Current Editorial Advisory Board Member News; and (6) a Special Feature on Cryptoassets and Blockchain.

One caveat regarding the Special Feature is that like all articles in the *GCARD*, the Special Feature's papers do not necessarily represent the views of the JPMCC, its sponsors, or donors.

Research Council Corner

The following authors contributed articles to the Research Council Corner: (a) Dr. Bluford Putnam of the CME Group; (b) Dr. Brock Mosovsky of cQuant.io and Mr. Lance Titus of Uniper Global Commodities; and (c) Mr. Robert Greer, Scholar-in-Residence at the JPMCC and Member of PIMCO's Index Oversight Committee. Dr. Putnam, Mr. Titus, and Mr. Greer are each members of the JPMCC's Research Council.

Dr. Bluford Putnam's thought piece explores the following four factors in analyzing the long-term prospects for crude oil and natural gas: (1) the evolving nature of oil production sensitivity to price changes, (2) the role of U.S. exports in the globalization of oil and natural gas prices, (3) the impact of electric cars and increasing transportation efficiencies on the demand for oil, and (4) the trends in the generation of electrical power away from coal and towards natural gas and alternative sources. Dr. Putnam presented on these topics to a panel of energy experts at the U.S. Energy Information Administration in Washington, D.C. on September 27, 2018. This panel, in turn, was organized by Dr. Thomas Lee of the U.S. Energy Information Administration; Dr. Lee is also a member of the *GCARD*'s Editorial Advisory Board.

Dr. Brock Mosovsky and Mr. Lance Titus, in turn, continue with the energy theme in the current issue of the *GCARD*. Their technical article is the second in a two-part series on renewable Power Purchase Agreements (PPAs), in which they explain PPA valuation and risk assessment. Part 1 of the series was published in the Summer 2018 issue of the *GCARD*. Consistent with the JPMCC's mission of covering all segments of the commodity field, the topic of renewable energies has also been featured prominently during the JPMCC's Research Council meetings; Till (2016), for example, summarizes a JPMCC Research Council presentation on wind-and-solar projects in California.

The third and final article in this section is provided by Mr. Robert Greer, who has been a stalwart supporter of both the JPMCC and the *GCARD*. We interviewed Mr. Greer in the Winter 2017 issue, and he generously contributed to the *GCARD*'s inaugural issue in the Spring 2016 edition. In the current edition of the *GCARD*, Mr. Greer contributes to the understanding of how commodity investing can fit into comprehensive portfolios.

Research Digest Articles Section

In this section of the *GCARD*, Professor Ana-Maria Fuertes of Cass Business School, City, University of London (U.K.) summarizes two scholarly papers, which examine commodity price movements from two very different perspectives. The first paper analyzes the underlying factors driving Commodity Trading Advisor returns; of note, the Spring 2016 issue of the *GCARD* also covered areas related to this subject. The second paper analyzes the "impact of commodity price movements on child mortality … [in] low and lower-middle income countries." This research article concludes that an "effective approach to improving child wellbeing … should combine hedging, import diversification and improvements … [in] institutional quality." Such policy recommendations were also covered in Till (2011) during the aftermath of destabilizing grain price spikes earlier in the decade.

Contributing Editor's Section

We further explore the conditions that determine the success or failure of futures contracts in Contributing Editor's Section. We have briefly analyzed this topic in articles in the Spring 2016 issue, which provided an overview of the subject, and in the Summer 2018 issue, which discussed a number of new commercial circumstances that ushered in the intense need for hedging instruments. In the current issue, we examine the history of futures regulation and conclude that a futures contract's success is also determined by how onerous relevant regulations or laws are. These three articles were drawn from a lecture that was provided by the author to staff from the Shanghai Futures Exchange.

Industry Commentaries

This issue's Industry Commentaries section includes articles from three energy experts who have past or present ties to policymaking in Washington, D.C. The authors in this section of the *GCARD* are as follows: Mr. Adam Sieminski, President of KAPSARC (Saudi Arabia) and former Administrator of the U.S. Energy Information Administration; Mr. Robert McNally, President of Rapidan Energy Group and former Senior Director for International Energy on the U.S. National Security Council; and Dr. Agnia Grigas, Nonresident Senior Fellow at the Atlantic Council (Washington, D.C.).

Dr. Agnia Grigas, Ph.D., during the launch of her book, The New Geopolitics of Natural Gas (Harvard University Press, 2017), at the Atlantic Council in Washington, D.C. on September 12, 2017. Dr. Grigas covers the salient points of her book in this issue of the *GCARD*.

Mr. Adam Sieminski's article summarizes research on the value to the global economy of OPEC's spare capacity. With spare production capacity, a swing producer can neutralize the impact of oil shocks, preventing damage to the global economy. He acknowledges that North American shale oil has made non-OPEC supply much more reactive to price, a point also emphasized in Dr. Bluford Putnam's article in this issue of the *GCARD*. However, Mr. Sieminksi notes that "shale oil is also subject to potential logistical constraints," and "it does not suffice to rapidly offset unanticipated shocks of large magnitude;" therefore, OPEC spare capacity still provides value in stabilizing oil markets.

Mr. Sieminski's article is a welcome addition to the *GCARD*'s past coverage of oil spare capacity issues. This past coverage has included an examination of when OPEC spare capacity has been the most important factor in determining oil prices, which was covered in the Spring 2016 issue of the *GCARD*. In addition, the Winter 2017 issue of the *GCARD* included an article that illustrated one way of incorporating shale excess supply, in addition to OPEC spare capacity, in considering overall spare production capacity.

Mr. Robert McNally's article, in turn, describes how the oil market is in a new era marked by boom-and-bust price swings in the absence of a credible swing producer. For a number of structural reasons, Mr. McNally argues that shale producers cannot cooperate to stabilize prices; they "are extremely diverse regarding resources and capital structure, they pursue growth targets instead of price stability, and they abide by punitive anti-trust laws."

Mr. McNally's article continues the debate in the pages of the *GCARD* on how to define the concept of swing producer. Previously, an article in the Fall 2016 issue of the *GCARD* asked whether North American shale producers could be considered the new swing oil producers. That article concluded the answer is perhaps yes, but only imperfectly so, given that it may take up to 12 months for fairly uniform production decisions to be made.

Dr. Agnia Grigas provides the final article in this issue's collection of Industry Commentaries. She covers both the transformation of the global natural gas markets and the rise of the liquefied natural gas (LNG) trade, which are causing shifts in global geopolitics. The *GCARD* began covering the significant changes in the LNG markets in an article in the Spring 2017 issue. That article described both the large increases in capacity and the ensuing changes in contractual conditions, governing this market. In the Winter 2017 issue, we included an article on the non-market forces that are contributing to a narrowing of inter-regional price differences in the LNG markets. On a related note, Dr. Bluford Putnam's article in this issue of the *GCARD* discusses how U.S. exports of LNG will increasingly link markets around the world. We are grateful for Dr. Grigas' article in adding the geopolitical dimension to our understanding of the sea-changes in the LNG markets.

Editorial Advisory Board Member News

In this issue of the *GCARD*, we are initiating a new section on Editorial Advisory Board (EAB) Member News. The *GCARD*'s EAB 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. In the News section, we update readers on the books and conferences that board members have respectively contributed to or participated in.

Special Feature on Cryptoassets and Blockchain

Another new feature of the *GCARD* is the inclusion of a Special Feature section. In this issue, we focus on cryptoassets and blockchain. But how does this topic fit in a digest devoted to covering commodities? The answer is two-fold. [1] At this point, virtual currencies are considered commodities from a U.S. regulation standpoint (Commodity Futures Trading Commission (CFTC), 2018). [2] In addition, blockchain may have applications in commodity trading. Concerning the latter possibility, the Summer 2018 issue of the *GCARD* summarized a presentation from the JPMCC's 1st International Commodities Symposium whereby the lecturer discussed how "blockchain technology … [could] digitize receipts and bills of lading, leading to faster shipping times and potentially safer financing of commodities by preventing the unsavory practice of pledging commodity collateral to multiple lenders."

In the current issue of the *GCARD*, we are delighted to provide a special feature of four articles on this complex topic, starting with a wonderful educational piece by a team of researchers at Société Générale. This section also includes articles from researchers at the Federal Reserve Bank of San Francisco as well as from the following two industry leaders: Ms. Julie Lerner of PanXchange (who authored an article) and Mr. Don Wilson of DRW (who is interviewed.) Summaries of the four articles follow.

Mr. Mark Keenan, Managing Director, Global Commodities Strategist and Head of Research for Asia Pacific at Société Générale Corporate & Investment Bank, presenting in Singapore on November 22, 2017. Mr. Keenan is also a member of the *GCARD*'s Editorial Advisory Board and is a co-author of an educational piece on cryptoassets and blockchain in this issue of the *GCARD*.

For the first article in the special feature, the *GCARD* is very fortunate to be able to include an accessible, comprehensive, educational article on cryptoassets and blockchain from the following Société Générale authors: Mr. Mark Keenan, Dr. Michael Haigh, Mr. David Schenck, and Mr. Klaus Baader. Mr. Keenan, in turn, also contributed to the Summer 2018 issue of the *GCARD* with a summary of his book, Positioning Analysis in Commodity Markets.

(We are also happy to announce that congratulations are in order to Mr. Keenan: his Summer 2018 *GCARD* article was cited authoritatively by the *Financial Times* (U.K.) in July 2018.)

The second article in this issue's special feature covers how futures trading plausibly impacted bitcoin prices. This article is provided by Dr. Galina Hale (Federal Reserve Bank of San Francisco), Dr. Arvind Krishnamurthy (Stanford Graduate School of Business), Dr. Marianna Kudlyak (Federal Reserve Bank of San Francisco), and Mr. Patrick Shultz (formerly with the Federal Reserve Bank of San Francisco.)

Next, our special feature looks into industry applications of the new technologies in question. Ms. Julie Lerner of PanXchange provides a realist's perspective on implementing blockchain in commodity trading, discussing the barriers to adoption. Still, she sees "the potential for blockchain to indeed be transformative," predicting "that energy traders will be the first to adopt the blockchain in the physicals space, as they tend to be the most technologically savvy." She predicts "metals next, then agricultural products last."

Ms. Julie Lerner, Chief Executive Officer, PanXchange, presenting at the JPMCC's 2nd International Commodities Symposium at the University of Colorado Denver Business School on August 14, 2018.

For a further industry perspective, we turn to an interview with Mr. Don Wilson, CEO of DRW; and Co-Founder and Board Member of Digital Asset Holdings, in the concluding article of the special feature. Mr. Wilson's Chicago-based firm became involved in cryptoassets and blockchain in three different ways: they bought bitcoin, established a trading desk, and co-founded the distributed ledger technology firm, Digital Asset Holdings. Mr. Wilson predicts that "[m]any ideas and projects in the marketplace will fail, but that process will give rise to better ideas and projects. Our perspective is that many will go on to make a significant impact on the world."

Conclusion

In closing, we would like to thank Dean Rohan Christie-David for his support of the JPMCC's *Global Commodities Applied Research Digest* in addition to expressing gratitude to the CME Group Foundation for generously sponsoring the *GCARD.* We would also like to extend a warm welcome to the [Chartered Alternative Investment Analyst] (CAIA) Association as the *GCARD*'s latest professional society partner.

Best Regards,

Hilary Till

Hilary.Till@ucdenver.edu

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

References

CFTC, "Federal Court Finds that Virtual Currencies Are Commodities," Press Release Number 7820-18, October 3. Accessed via website:
https://www.cftc.gov/PressRoom/PressReleases/7820-18 on October 31, 2018.

Linares, A., 2018, "International Commodities Symposium Focuses on Real-World Application," *CU Denver Business School News*, August 23. Accessed via website:
https://business-news.ucdenver.edu/2018/08/23/international-commodities-symposium-focuses-on-real-world-application/
on October 31, 2018.

Till, H., 2011, "A Review of the G20 Meeting on Agriculture: Addressing Price Volatility in the Food Markets," EDHEC-Risk Institute Position Paper, July. [Ms. Till is also a Research Associate at the EDHEC-Risk Institute.] Accessed via website:
https://risk.edhec.edu/publications/review-g20-meeting-agriculture-addressing-price-volatility-food-markets on October 31, 2018.

Till, H., 2016, "December 4th, 2015 Meeting: Morning Panel Session on 'The Transition to the Next Generation of Energy Sources'", JPMCC Research Council Report, April. Accessed via website:
http://www.jpmcc-gcard.com/wp-content/uploads/2018/10/JPMCC-Research-Council-Report-120415.pdf on October 31, 2018.

Four Ideas to Consider When Analyzing Long-Term Prospects for Oil and Natural Gas

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

Dr. Bluford Putnam, Ph.D., Chief Economist of the CME Group, presenting at the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018. Dr. Putnam lectured during the first day's plenary session, participating in the conference's Applied Commodity Research Leaders Forum. He is also a member of both the JPMCC's Research Council and its Advisory Council.

Periodically, analysts and forecasters benefit from spending some time thinking about what might be the most disruptive developments that could materially change the way we analyze markets over a long-term horizon. In this research, we provide a perspective on four developments that may shape oil and natural gas markets as they evolve during the 2020s. We want to explore (1) the evolving nature of oil production sensitivity to price changes, (2) the role of U.S. exports in the globalization of oil and natural gas prices, (3) the impact of electric cars and increasing transportation efficiencies on the demand for oil, and (4) the trends in the generation of electrical power away from coal and towards natural gas and alternative sources.

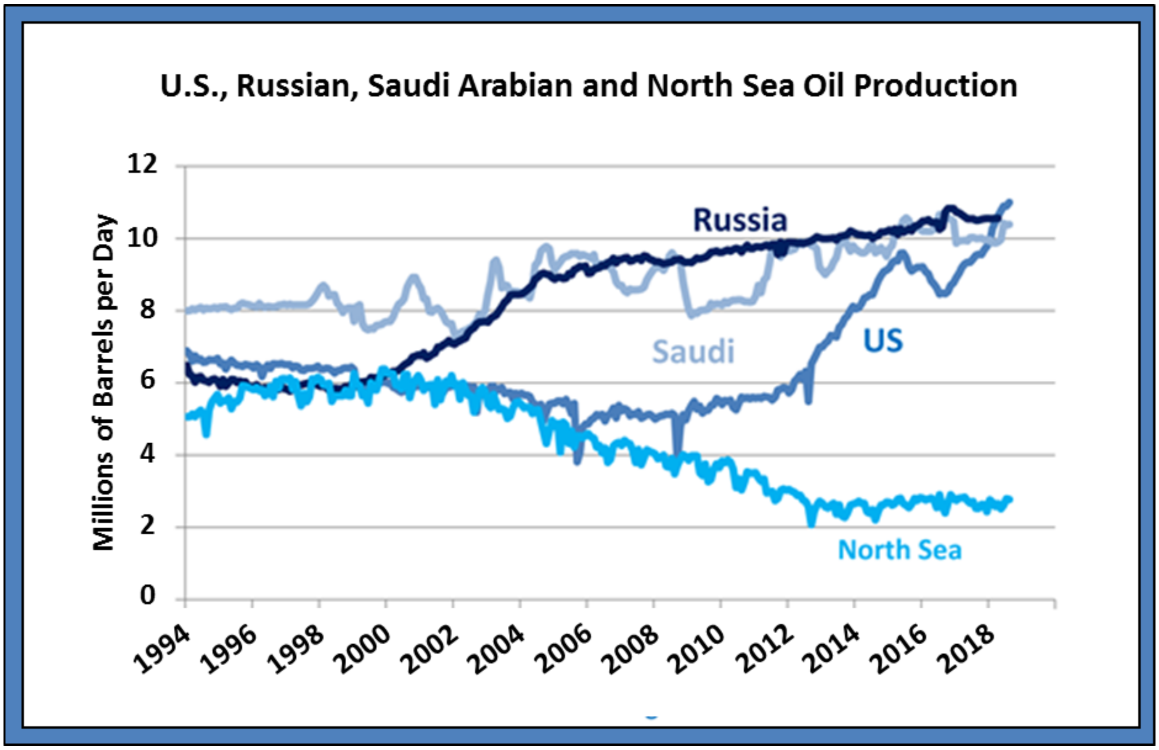
1. Increasing Medium-Term Elasticity of Oil Supply Effectively Makes U.S. the Swing Producer

Traditional oil wells can keep on pumping for decades, and once they start producing oil the marginal cash costs of keeping these wells operational and pumping are extremely low. The difference with shale wells could not be more striking.

Shale oil wells have a very predictable two years or so lifespan from when drilling begins to when the well has pumped its last drop and been shut off and sealed. Once a shale oil well has started production, it will almost always be allowed to run its course. The question is: does the production company drill more wells? The answer depends critically on a number of factors, of which price is extremely important. If the price of oil is such that the all-in capital and operating costs can be covered and leave a reasonable profit given the risks and financing costs, then the producer will consider drilling new wells. An important note here is that when we speak of the price of oil in this sense, we are talking about the fully hedged estimated production of the shale well over its expected lifetime – that is, the spot price is interesting, but what matters in terms of price is the shape of the oil futures maturity curve over the expected life of the well. The producer may or may not choose to hedge or to hedge only part of the expected production, but our price analysis starts with the fully hedged assumption.

Other factors beyond price also play critical roles. Shale oil wells require workers with specific skill sets. Large quantities of sand and water need to be available at the drilling site. Drilling processes involve specialty steel – is the steel available and at what cost? Unlike traditional wells, shale oil wells use a lot of electricity, which must be delivered to the well site. There is considerable truck traffic involved. Can the roads handle the traffic? Once the oil is pumped, how will it be delivered to the nearest storage terminal or port? And, of course, there are the financing challenges. Can the well's capital costs be financed from the free cash flow of the production company, or does the investment capital need to be borrowed or equity raised? All of these factors – workers, sand, water, steel, electrical grid, road traffic, pipeline and storage facilities, and financing costs – may come with variable prices and serious timing constraints, depending on market conditions.

Figure 1
Major Sources of Oil Production



Source: Bloomberg Professional (DOETCRUD, OPCRSAUD, DWOPRUSS, PIWANORT).

The point is that one may have a pretty good sense of the all-in costs of a shale oil well from start to finish, but there are plenty of potential challenges that must be overcome beyond just the price of oil before the well goes into production. So, while knowing the oil price and shape of the oil futures maturity curve is critical, the oil price is not remotely the only factor determining future production.

Even with these caveats, shale oil well production is likely to be much more price sensitive than existing traditional oil supply. If the oil price drops dramatically, as it did in late 2014 and 2015, then shale oil production will decline, too, by a large amount, but with a lag, which can be seen in the abrupt change in U.S. oil production in Figure 1. Existing wells will be run until they are done. The production adjustment lag will come as new wells are not drilled at the former pace. And, if the oil price rises materially above expected costs, financing may become abundant, and the new wells will be put in place at an ever increasing pace, subject to the constraints of workers, sand, water, steel, and the road, pipeline, storage, and electrical infrastructure.

As we look back from 2018, we only have two meaningful observations of the price sensitivity of U.S. shale oil production – the oil price decline of Q4/2014 through Q1/2016, and the oil price rise in 2017 and 2018. In both of these two cases, with a lag, production responded very aggressively as suggested here. The only non-shale supplier of oil that is price sensitive is Saudi Arabia, and that is because they have historically made a choice to buffer the volatility of oil prices and serve as a swing producer, the economic value of which is estimated in Sieminski (2018). The implications of this analysis are that the elasticity of U.S. shale oil production in the medium-term will serve as a powerful offset to the ability of Saudi Arabia to influence global prices in the way they were once able to do. This in turn may make Saudi Arabia less willing over time even to serve as a swing producer. And from an econometric forecasting perspective, if one's model is based on legacy price-production elasticities, pre-shale revolution, then those model's may be very far off the mark going forward.

2. U.S. Exports Will Speed the Globalization of Oil and Natural Gas Prices

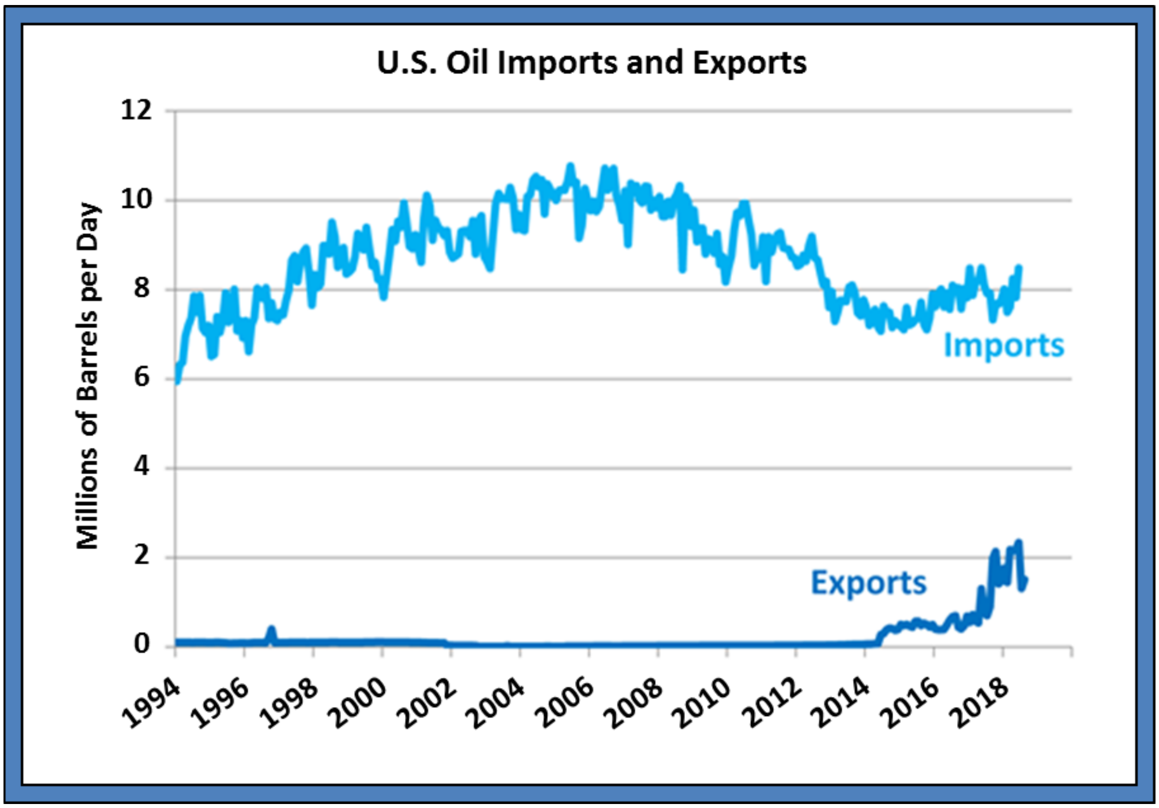
In December 2015, the U.S. lifted its ban on oil and natural gas exports, which had been in place as a response to the large oil price rises engineered by the Organization of Petroleum Exporting Countries (OPEC) back in the 1970s. While the U.S. remains a large importer of oil and petroleum products, the export response has been rapid and impressive, as shown on the next page in Figure 2. And the implications are huge for the price interactions between U.S. produced oil and natural gas and production elsewhere around the globe.

Take the Brent (North Sea) oil price spread relative to the U.S. West Texas Intermediate (WTI) crude oil price. Before the U.S. shale oil revolution, the price spread between Brent and WTI was volatile yet close to zero. Then, in 2012-2013, U.S. shale oil production overwhelmed the pipeline infrastructure and U.S. oil prices became disconnected from the rest of the world. The price of Brent relative to WTI moved above $10/barrel and then above $20/barrel. Market forces involving the transportation of oil came into play, especially rail transport from the Bakken shale oil fields of North Dakota to the refineries in New Jersey. Rail transport costs were in the $10/barrel range to get the shale oil to the east coast refineries where it directly competed with North Sea oil and Middle Eastern oil benchmarked to Brent. The spread dropped to around $10/barrel. As the pipeline infrastructure improved as well, the Brent-WTI spread collapsed further. The removal of export prohibitions also changed the price spread dynamics by placing the point of direct competition in Europe and China, and the Brent-WTI spread entered a new phase. In 2018, two old themes reappeared. U.S. shale oil production in the Permian basin expanded so rapidly with rising prices that the infrastructure to get the oil to Texas and Louisiana export terminals was again overwhelmed at the same time as production dropped in Venezuela and Libya due to internal political turmoil and in Iran due to the bite taken out of production by U.S. economic sanctions. The Brent-WTI spread responded by widening as it became clear that Saudi Arabia was not as aggressive a swing producer as it might have been in the past (see the conclusions to the price sensitivity section above.)

The bottom line is that with the U.S. serving as a serious oil exporter, the Brent-WTI price spread is going to respond to the relative dynamics at the point where these strains of oil meet in direct competition. As the U.S. infrastructure challenges are resolved, the price spread is likely to be driven more by shipping costs to the points of competition, say China. In this sense, futures contracts such as the Houston physically delivered product (HCL) can be viewed partly as a transportation-driven spread relative to WTI (CME Group, 2018b).

The analysis with natural gas exports is similar but with longer time lags due to the costs of building the U.S. export infrastructure. Billions upon billions of dollars, however, have been put to work turning former import facilities for liquefied natural gas (LNG) into export facilities and building large capacity facilities to convert natural gas into LNG so it can be exported. Exports are increasing rapidly and a number of new export facilities will come on line over the next few years, allowing exports of LNG to ramp up even more. One should also realize, though, that not all the expansion of export facilities are in the U.S. Competing countries, such as Canada, are building natural gas export facilities. A planned LNG facility costing upwards of $40 billion is likely to be built in Kitimat, British Columbia, on the Pacific coast. Compared to shipping LNG from Sabine Pass in the Gulf of Mexico, the distance to Shanghai or Tokyo will be cut by half or more, lowering shipping costs.

Figure 2
U.S. Oil Imports and Exports and Imports



Source: Bloomberg Professional (DOCRTOTL, DOEBCEXP).

And similarly to crude oil, one of the key pricing factors in the analysis of the spread between U.S. Henry Hub natural gas and natural gas pricing at the ports of entry in consumer countries such as China, Japan, and the European Union will be shipping costs, liquefaction costs, and de-liquefaction costs. In this sense, one should think of LNG not as a separate product from natural gas, but as a transportation product allowing natural gas to be used in places far away from its point of extraction. And again, futures contracts, such as the one based on the LNG delivery point at Sabine Pass are essentially going to serve as price discovery points for the all-in transport costs relative to the Henry Hub natural gas price (CME Group, 2018a). The relevant shipping distances from Sabine Pass are shown on the next page in Figure 3.

What we have developing here is a "Transpread" or transportation spread for crude oil based on Houston crude oil export terminal prices and for natural gas based on LNG export terminal prices. The "Transpread" is essentially just like the "crack" spread between crude oil and refined products like gasoline (RBOB), or the "crush" spread between soybeans and processed products such as soybean oil or soybean meal.

Figure 3
Shipping Distances

Distance from Sabine Pass	
Discharge Port	Nautical Miles
Gateway (NL)	5002
Tokyo	15762
Tokyo (via Panama Canal)	9209
Tokyo (via Suez Canal)	14521
Shanghai	15098
Shanghai (via Panama Canal)	10081
Shanghai (via Suez Canal)	13854

Source: SEA-DISTANCES.ORG, https://sea-distances.org/.

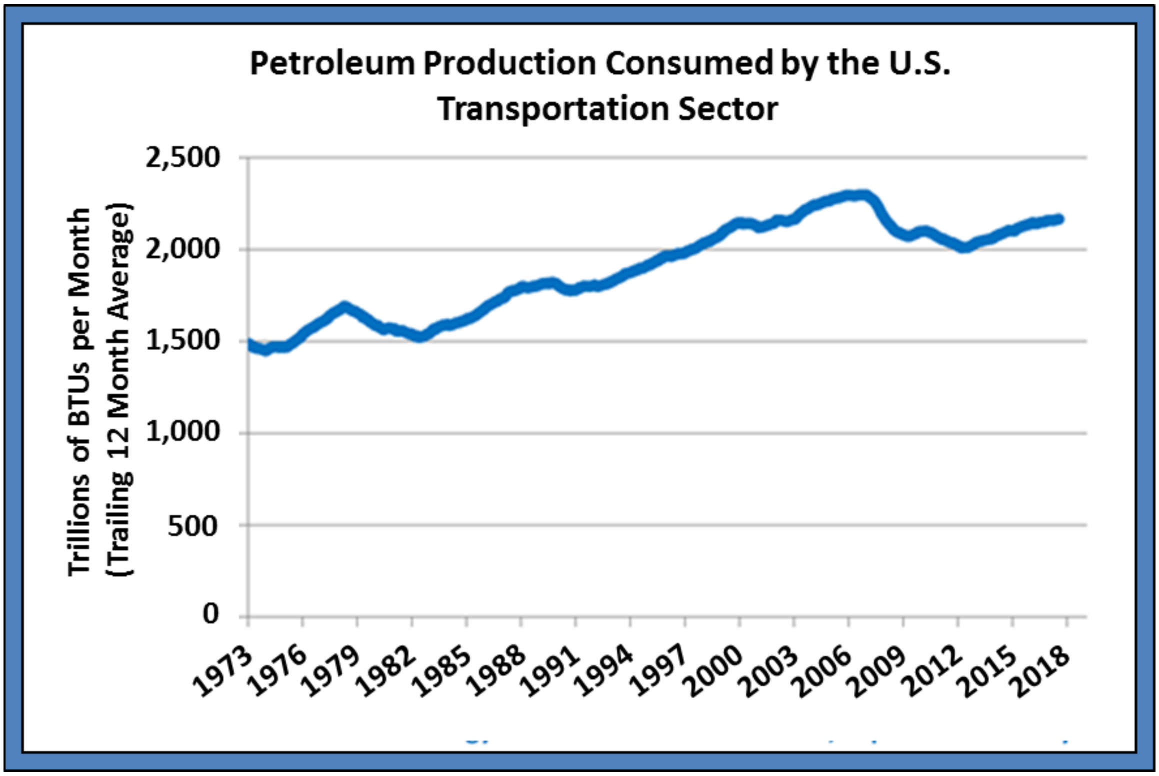
3. Electric Cars and Increasing Transportation Efficiencies Eventually Will Dampen Oil Demand Relative to GDP Growth

In 2018, and for a very long time into the past, in its refined state, oil has been mostly used as a transportation fuel. For example in the U.S., some three-quarters of crude oil find its way into the transport sector. The trend in petroleum consumed as a transportation fuel is shown on the next page in Figure 4. For countries that depend more heavily on diesel oil or heating oil to run electrical power plants or heat homes, then this percentage may be a little lower – for now. Nevertheless, the key issue for the 2020s will be whether transportation efficiencies have a material and negative impact on the global demand for crude oil.

We expect continued efficiencies in shipping and in airline travel to have steady and incremental impacts on the demand for oil relative to GDP growth. That is, the elasticity of oil consumption relative to GDP is likely to slowly decline.

The real game changer may be electric automobiles. Of course, this game changer has been promised for a long time (if not by yours truly) and the demand impacts have been extremely small. Electric vehicles are available, but in 2018 they represent only a very tiny proportion of vehicles or total miles driven. Will that change in the 2020s? And if electric vehicles gain traction will that have a noticeable impact of the demand for crude oil relative to GDP growth?

Figure 4
Petroleum as a Transportation Fuel in the U.S.



Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, September 2018, Table 2.5, "Transportation Sector Energy Consumption."

Our answer to the first question is that electric vehicles, including hybrids, are going to have a major impact on the automobile market in the 2020s. The reason is that these electric vehicles are going to change the way people drive, not just change the way the automobile is powered. This is a critical distinction. Electric vehicles will be loaded with the latest in artificial intelligence to enable (semi-) self-driving capabilities that will mean much safer driving along with more efficient driving times. The analogy is with smart phones. Smart phones added so many features, from photography to social networking that they were hardly at all like legacy cell or mobile phones. The advent of the smart phone was only a decade ago, and it changed everything. That is the point we are making with electric vehicles – they will change car-buying and driving habits in a material way. The key to this development is the commitment from the major automobile producers to embrace electric vehicles, and their capital expenditures testify that this is happening, even if the promised sales explosion may not happen until the mid-2020s. The other game-changers for electric vehicles will be the vast expansion of recharging facilities, improvements in the speed of recharging, and potential new government regulations promoting electric vehicles in place of gasoline engines and possibly eliminating the production of new diesel vehicles for automobiles if not trucks and farming equipment.

Besides the question of future consumer preferences, there are infrastructure impediments to the expansion of electric vehicles – namely the rare earths used in battery technology. It is worth pointing out that rare earths are not actually that rare. But in mineral deposits, they come in various combinations of rare earths and the isolation and extraction processes can be extremely expensive. This means there are some important challenges technically to be solved before we see a massive expansion of electric vehicles on the road.

If electric vehicles do gain traction in the 2020s, what does it mean for oil demand? Well, if one believes the past is a good guide to the future, then one would make some calculations such as the time it takes to turn over the automobile fleet given an average age well above a decade. Then, one would also calculate the actual fuel savings based on current technology. This detailed, bottom up, historical approach will probably leave one unconvinced that an electric automobile revolution will have a material impact on the long-term demand for crude oil. The problem we have with this approach is that we do not believe that the past is necessarily a useful guide to the future. If electric automobiles are more like smart phones, if driving habits change materially, if regulations incent the use of electric vehicles over gasoline-powered vehicles (for example, in China or the European Union, if not in the U.S.), then the aging fleet of gasoline-powered vehicles could turn over in record time with no regard to the current average age of an automobile on the road in 2018. These are truly big "ifs" and the detailed historical analysis may prove correct. Time will tell, yet our view is that automobile buying preferences will change dramatically in favor of electric automobiles, that driving habits will change, and that regulations will change on a global scale such that the growth of demand for oil will be reduced in relation to GDP growth.

Of course, this also implies that the global economy will require considerably more electrical power generation. If gasoline is being displaced by electricity, what power source will drive the expanded electricity demand? Yes, one might have guessed – natural gas.

4. Role of Natural Gas in the Generation of Electrical Power to Increase Sharply Around the World

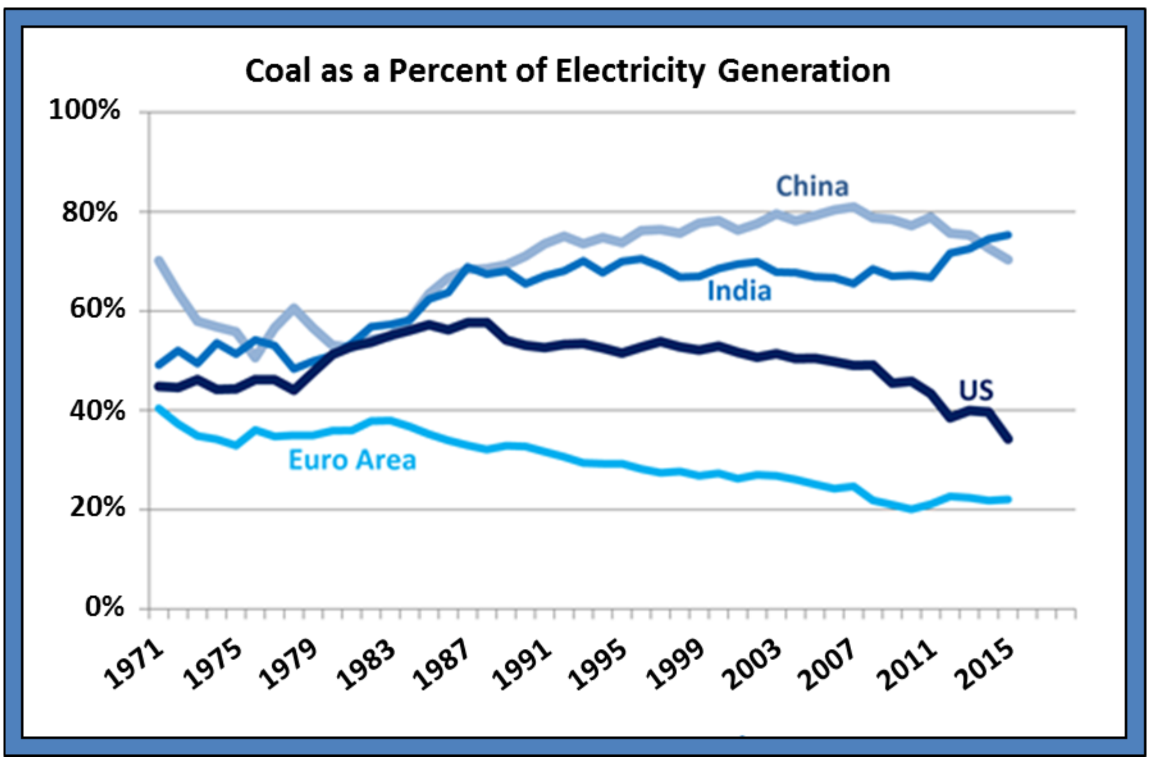
Despite the U.S. regulatory thrust in the other direction, natural gas and other alternative fuels are gaining market share from coal as a fuel for electrical power generation. The trend, as seen in Figure 5 on the next page, is quite powerful and being driven by demographic and economic forces. As countries acquire wealth and as their populations live longer, there is naturally an increasing desire for wealth preservation and improved health systems. With regard to the latter, the environmental gains from switching electrical power generation from coal to natural gas and other alternatives are considerable. Moreover, the potential supply of natural gas from new fields such as the huge Delaware basin within the Permian region of Texas and New Mexico, or more production of natural gas from Saudi Arabia, or even increased production as costs are reduced over time by China and East Asian countries suggest that the economics puts natural gas in a favored position to increase market share in a rapidly expanding market for electrical power generation. At this point, a few country-by-country comments are worth noting.

China has a major push underway to relieve its dependence on coal for electrical power generation in favor of natural gas and other sources. In this case, other sources involve hydroelectric facilities as a number of very large dams are under construction, as well as subsidizing solar power farms. Still, natural gas is likely to be a major contributor to the objective of reducing dependence on coal. And, given the costs of natural gas as an LNG import, China and other East Asian countries will have powerful incentives to expand their own production of natural gas as extraction technologies to get at deep underground basins of natural gas become more economical.

India is still expanding the market share of coal in electrical power generation. Pollution is a big challenge, but for now it is overwhelmed by cost considerations. India's ability to increase use of natural gas in electrical power generation may well depend on whether less expensive sources of natural gas will be coming from Saudi Arabia if it ramps up natural gas production to compete with Qatar over the next decade. As discussed earlier, shipping costs are critical, and if more close-by sources develop, this could lead to faster adoption of natural gas for electrical power generation in India.

In some countries, such as Mexico, natural gas is taking market share from oil. As typical, infrastructure issues will play a role in how fast Mexico expands natural gas inputs. In this case, there are likely to be more pipelines built inside Mexico to connect to U.S. pipelines coming from the Permian basin.

Figure 5
Market Share of Coal in Electrical Power Generation



Source: International Energy Agency (IEA) Statistics © OECD/IEA (http://www.iea.org/stats/index.asp).

Japan is an interesting case, and one in which politics may play a large role. The U.S. approach to North Korea as well as the U.S.-China trade tensions has made some Japanese politicians, including Prime Minister Abe, even more interested than perhaps they already were in the building up Japan's military capabilities so it can take care of itself and not depend on the U.S. Now that Prime Minister Abe has a secure hold on the leadership of his Party, he can expect to cut the ribbon at the 2020 Olympics as well as push for changing the constitution to allow more than a defensive military capability. This, in turn, suggests that the Prime Minister may well buck popular opinion and proceed more rapidly than expected with restarting nuclear power facilities shut down after the earthquake and tsunami of 2011. After the nuclear facilities were shutdown, natural gas picked up a large share of electrical power generation. Then, oil also gained due to the high cost of importing LNG. In the 2020s and into the 2030s, and we are indeed talking decades here, the political analysis suggests that nuclear power will regain some market share, oil and coal will lose market share due to environmental concerns, and natural gas will be the beneficiary along with nuclear.

Bottom Line

- U.S. shale oil production will respond with a one-year or so lag in an aggressive manner to future changes in the price of oil. Interestingly, this may make Saudi Arabia less willing to be a swing producer.

- U.S. exports of crude oil and LNG will increasingly link markets around the world. In this regard, shipping costs will be one of the critical factors in the spread between U.S. WTI crude oil and various Europe and Middle Eastern oil supplies, just as these costs will also be critical to the price spread between Henry Hub natural gas and regional natural gas markets in Asia, India, and Europe. New oil delivery futures contracts based on Houston ports and LNG futures contracts based on Sabine Pass can be considered as transportation links to U.S. domestic prices, creating a kind of "Transpread" to mirror the "crack" spreads from oil to refined products and "crush" spreads from soybeans to meal and oil.

- The impact of electric cars and increasing transportation efficiencies on the demand for oil may be material if electric cars change driving habits like smart phones changed communications and social media.

- The global trend in the generation of electrical power away from coal and towards natural gas and alternative sources will continue and possibly even get much stronger.

Endnotes

The author is indebted to Dr. Thomas Lee as organizer and the various participants in the in-depth discussions that occurred at the September 27, 2018 conference in Washington, D.C. at the U.S. Energy Information Administration on the topic of the "Dynamics of Oil, Natural Gas, and LNG Markets" and as covered in this issue's Editorial Advisory Board News section. [Dr. Thomas Lee is a Senior Economist in the Office of Energy Markets and Financial Analysis at the EIA and is also a member of the *GCARD*'s Editorial Advisory Board.]

We must thank Professor Ron Ripple, Mervin Bovaird Professor of Energy Business and Finance, Collins College of Business, University of Tulsa. Professor Ripple is a forceful advocate of thinking of LNG as a transportation device for natural gas rather than as a separate product with its own market dynamics. The reality is that no one uses LNG as a fuel source since it must be de-liquefied back to natural gas before being consumed. The fuel source is natural gas. LNG is the transport vehicle.

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.

References

CME Group, 2018a, "CME Group and Cheniere Energy, Inc. Reach Agreement to Develop First-Ever Physically Deliverable LNG Futures Contract at Sabine Pass Terminal," Press Release, July 10. Accessed via website: https://www.cmegroup.com/media-room/press-releases/2018/7/10/cme_group_and_cheniereenergyincreachagreementtodevelopfirst-ever.html on October 20, 2018.

CME Group, 2018b, "CME Group to Launch Physical WTI Houston Crude Oil Futures Contract," Press Release, September 24. Accessed via website: https://www.cmegroup.com/media-room/press-releases/2018/9/24/cme_group_to_launchphysicalwtihoustoncrudeoilfuturescontract.html on October 20, 2018.

Sieminski, A., 2018, "The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy," *Global Commodities Applied Research Digest*, Industry Commentaries, Vol. 3, No. 2, Winter, pp. 88-91.

Author Biography

BLUFORD PUTNAM, Ph.D.
Chief Economist, CME Group

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

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

Dr. Putnam has authored five books on international finance, as well as many articles that have been published in academic journals, including the *American Economic Review*, *Journal of Finance*, and *Review of Financial Economics* among others. His newest book, Economics Gone Astray, will be available from World Scientific Press in early 2019.

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

Shaping and Hedging Renewable Power Purchase Agreements

Brock Mosovsky, Ph.D.
Director of Operations and Analytics, cQuant.io

Lance Titus
Managing Director, Uniper Global Commodities; and Member of the J.P. Morgan Center for Commodities' (JPMCC's) Research Council at the University of Colorado Denver Business School

Mr. Lance Titus (right), Managing Director, Uniper Global Commodities, presenting during the panel on "Emissions Trading" during the JPMCC's Research Council meeting on September 30, 2016. Mr. Titus is a member of both the JPMCC's Research Council and its Advisory Council and also serves on the Editorial Advisory Board of the *Global Commodities Applied Research Digest*. Dr. Daniel Kaffine (left), Ph.D., Professor of Economics at the University of Colorado Boulder, also participated in the "Emissions Trading" panel.

Renewable power purchase agreements (PPAs) have steadily increased in popularity over the last decade. They have enabled hundreds of megawatts of renewable energy development and have played important roles in many corporate and utility-led sustainability programs. As renewable PPAs have been accepted by a broadening range of market participants and as the intermittent nature of renewable generation has become better understood, PPAs themselves have increased in sophistication. Today, many PPAs include provisions designed to protect against uncertainty in renewable energy generation or volatile electricity market prices. Collectively, these protections fall under the umbrella of "shaping and hedging" and aim to provide one counterparty or another with increased certainty around future generation or cash flows.

This article is the second in a two-part series on renewable PPA valuation and risk assessment published in the J.P. Morgan Center for Commodities' (JPMCC's) *Global Commodities Applied Research Digest* (*GCARD*).[1] Herein, we outline methodologies for shaping and hedging renewable PPAs, and we discuss the benefits of each of these strategies from both the buyer and seller perspectives. We build up PPA value across a range of shaping scenarios of increasing granularity, identifying the incremental value of each refinement in shape. We also present a methodology for deriving optimal hedge ratios that can be used to enact a hedging program that minimizes risk to the buyer or seller and that is custom-tailored to a particular renewable facility or PPA.

Shaping Renewable Energy

In a shaped PPA, the seller guarantees the buyer a fixed generation shape—a predetermined quantity of energy delivered over a predetermined period of time. In exchange, the buyer guarantees that the seller will be compensated at the PPA price for all energy delivered under the contract or financially settled as a contract for differences ("CFD").[2] The shape guarantee may apply at the annual, seasonal, monthly, or even hourly level and, depending on the granularity of the shape profile, has the effect of removing some or all uncertainty in renewable generation (generation risk) from the buyer's position in the contract.

In addition to removing risk from the buyer's position in the PPA, shaping also has other benefits to the buyer. It can help align energy contracted under a PPA with the shape of the buyer's load (his native short position), giving the buyer greater confidence in managing his residual load position. A corporate buyer's load may be relatively flat compared to the highly variable generation produced by a wind or solar farm, and a shaped PPA can help to align supply and demand in a more predictable way than a unit-contingent or "as produced" PPA. In cases where a buyer's electricity tariff is directly related to wholesale market prices, the improved alignment with the buyer's load may allow the PPA to function as a better financial hedge against the buyer's native short physical position, providing protection against future electricity price fluctuations. Finally, shaping a PPA can better align contracted generation volumes with standard over-the-counter financial products, allowing the buyer to directly lock-in future value through hedging.

Such benefits of a shaped PPA do typically come at a cost, however, and sellers will demand a premium to assume the generation risk on behalf of the buyer. In any contracting scenario, the question becomes: how much of a premium is reasonable? The answer is highly dependent on the contract terms, the location of the facility, and the real-time dynamics of the renewable resource at the point of generation and the electricity prices at the settlement point. Each PPA has its own unique profile of value and risk and requires rigorous case-by-case analysis to properly understand the contractual implications to the buyer and seller.

Dr. Brock Mosovsky, Ph.D. (left), Director of Operations and Analytics, cQuant.io, with his colleague, Mr. David Leevan (right), Managing Director, cQuant.io, during the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018.

Shaped PPA Settlement Amounts

For all examples in this article, we assume that shapes guarantee a certain amount of generation in each hour (as opposed to each month, season, or year), though guaranteed volumes may vary hour-to-hour and month-to-month. This structure is sometimes known as an "8760 profile" since there are 8760 hours in a typical (non-leap) year and the shape guarantees a specific amount of energy to be delivered in each hour. As in the first article of the series, we also assume contracts are for virtual PPAs that settle financially each month. Under these assumptions, the buyer's settlement amount, $\boldsymbol{A_{buy}(h)}$, in any particular hour, h, for a shaped PPA is given by the equation,

$$\boldsymbol{A_{buy}(h)} = G(h)[\boldsymbol{p(h)} - K], \#(1)$$

where $G(h)$ is the guaranteed contracted generation amount in hour h, $\boldsymbol{p(h)}$ is the variable market price of electricity in hour h, and K is the fixed PPA price in dollars per megawatt-hour ($/MWh). Here we have used the convention that terms in bold font denote quantities that are uncertain in each hour over the contract horizon; these are the terms that impart risk to the PPA. From equation 1, it is easy to see that the buyer assumes no generation risk. That is, in any given hour, the only uncertain quantity is the market price, $\boldsymbol{p}(\boldsymbol{h})$.

The hourly settlement amount, $\boldsymbol{A_{buy}}(\boldsymbol{h})$, is the amount the buyer pays or receives in a given hour under the PPA. It may be either positive or negative, depending on the market price of electricity, $\boldsymbol{p}(\boldsymbol{h})$, in relation to the contract price, K. When $\boldsymbol{p}(\boldsymbol{h})$ is greater than the contract price, the buyer receives a payment; when $\boldsymbol{p}(\boldsymbol{h})$ is less than the contract price, the buyer makes a payment. Put another way, equation 1 is the buyer's hourly cash flow under the contract. It is equivalent to saying that the buyer pays the contracted price, K, for the guaranteed generation, $G(h)$, and also receives a payment in the amount of the real-time market price valuation of that generation.

Typically, PPAs settle monthly, which means that no cash actually changes hands until the end of the month. The monthly settlement amount is simply the sum of the hourly settlement amounts over all hours of the month. For the buyer, this is,

$$\boldsymbol{A_{buy}} = \sum_{h\ in\ month} \boldsymbol{A_{buy}}(\boldsymbol{h}). \#(2)$$

The seller's risk profile differs significantly from the buyer's risk profile. In a shaped PPA, the seller explicitly assumes the generation risk in the contract by guaranteeing some production level to the buyer. In practice, this guarantee is usually made at the P99 level, or the production profile that will be met with 99% statistical confidence; the P99 profile is often used to size debt service coverage ratios for financing new renewable projects. When actual facility production is below the shaped level, the seller must purchase energy from the market to make up the difference; when actual production is above the shaped level, the seller may liquidate the residual energy into the market at the prevailing real-time price. This is in contrast to a unit-contingent PPA where no guarantee on generation is made and the buyer simply accepts all or a prorated share of the energy produced by the renewable facility in each hour. Regardless of generation level, the seller of a shaped PPA is guaranteed to receive the contracted price, K, for each unit of energy covered under the shape. As such, the seller's settlement amount, $\boldsymbol{A_{sell}}(\boldsymbol{h})$**,** in a particular hour, h, for a shaped PPA is given by the equation,

$$\boldsymbol{A_{sell}}(\boldsymbol{h}) = G(h)K + [\boldsymbol{g}(\boldsymbol{h}) - G(h)]\boldsymbol{p}(\boldsymbol{h}), \#(3)$$

where $\boldsymbol{g}(\boldsymbol{h})$ is the actual generation produced by the facility in hour h and all other terms are as defined in equation 1. This equation states that the buyer's hourly settlement amount is the guaranteed generation (the contracted shape) valued at the contracted price plus the difference between actual and contracted production valued at the prevailing real-time market price.

Rearranging terms in equation 3 helps to more clearly isolate the elemental components of risk for the seller:

$$\boldsymbol{A_{sell}}(\boldsymbol{h}) = G(h)K + \boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h}) - G(h)\boldsymbol{p}(\boldsymbol{h}). \#(4)$$

From this equation, we see that the first term, $G(h)K$, is entirely determined at contract signing and contains no uncertain quantities. This represents the guaranteed payment from the buyer for the contracted energy shape. The second term, $\boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h})$, is the product of two uncertain quantities in each hour: the realized hourly generation and the real-time market price. The fact that these two uncertain quantities are multiplied together has important implications for the seller's risk; effectively, the generation and price risk can have a magnifying effect on each other. We discuss this magnification of risk in more detail below in the section on hedging. The final term in equation 4, $G(h)\boldsymbol{p}(\boldsymbol{h})$, contains only price risk and is identical to the buyer's price risk in equation 1 up to a difference in sign.

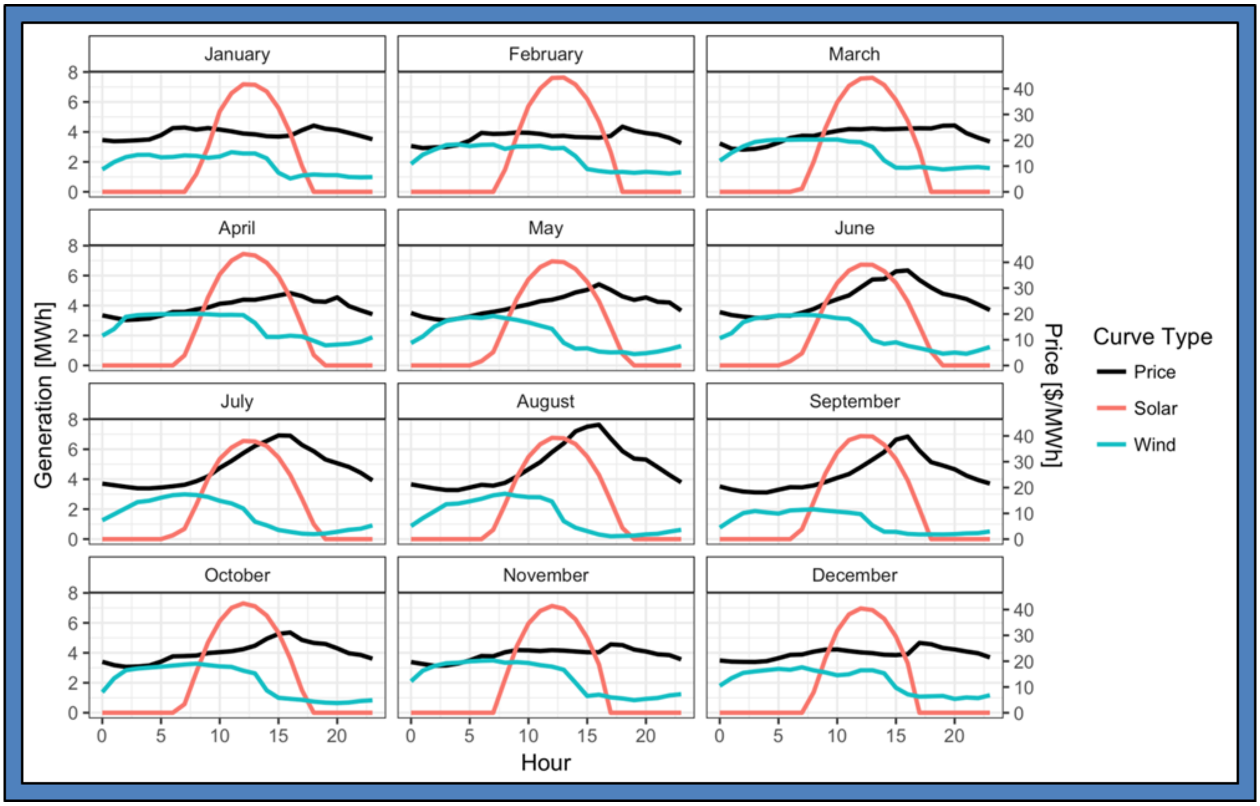
Example PPAs – Wind and Solar in Texas

In order to demonstrate the practical implications of the shaping equations above, the value of shaping contracts at varying levels of granularity, and the optimal ways in which shaped contracts can be hedged, we examine several virtual PPAs settled against Electric Reliability Council of Texas (ERCOT) North Hub real-time prices. The PPAs are based on hypothetical wind and solar farms in central Texas located approximately 150 miles northwest of San Antonio. The solar farm is assumed to be a 10 MW DC fixed array with a panel tilt angle optimized for maximum annual energy production. The wind farm is assumed to be composed of Siemens SWT-2.3-108 wind turbines, and the full wind farm capacity is scaled so that its expected annual energy production is identical to that of the solar farm. This scaling eliminates any volumetric bias in aggregate between the two renewable resources and their valuations. Since we also use a consistent set of simulated market prices[3] to value the solar and wind PPAs, any differences in value and risk are the direct result of differences in the timing of generation and its alignment with both market prices and contract specifications. We assume a 5-year contract term beginning in January of 2019 and running through December of 2023.

A primary driver of PPA value is the alignment between the shape of generation and the shape of prices at both the monthly and hourly levels. The fair market value of a given PPA is essentially the expected generation-weighted average market value of energy to be produced under the contract. As such, generation during hours when market prices are above average will increase PPA value while generation during hours when market prices are below average will decrease value. In either case, higher generation levels in a given hour will produce a larger effect on PPA value for that hour. That is, when all other variables are held fixed, a generation shape that is highly coincident with the shape of market prices will have more value than one that is misaligned with market prices.

Figure 1 on the next page shows the alignment of median hourly solar and wind generation shapes (known as the P50 shape) with ERCOT North real-time prices in each calendar month. The plots show a stark contrast between the coincidence of the two generation types with market prices. Summer ERCOT North electricity prices show a very strong hourly shape with evening prices being more than twice the value of early morning prices at the median from June through September. Solar generation takes advantage of this strong mid-day rise in prices with peak power output occurring just a few hours before the evening peak price. Despite the solar peak occurring slightly before the evening price peak, there is generally a strong correspondence between elevated solar generation and elevated price, resulting in enhanced overall value for solar PPAs.

Figure 1
Median (P50) Hourly Generation and Price Shapes



Notes: Generation curves reflect hourly median simulated generation from 2007 through 2012 based on historical wind speed and solar radiation data obtained through the National Solar Radiation Database and the NREL Wind Integration National Dataset. Price curves reflect hourly median ERCOT North real-time spot prices over the period from January 2014 through June 2018.

Source of image: cQuant.io ReAssure PPA®.

Wind generation, on the other hand, peaks in the early morning hours and tends to ramp down just as prices begin to rise in the early afternoon. The median wind generation shape virtually mirrors the price shape in May through October; this assigns greater weight to hours with lower market prices and tends to drag PPA value downward. The summer misalignment between wind generation and price is only partially mitigated in the winter when elevated prices in the early morning do coincide with high wind generation. However, the winter evening hours show the opposite trend with wind generation falling off just before the evening peak in price.

While the plots in Figure 1 help to paint a picture of the value of shaping the PPA relative to intra-day patterns in generation and prices throughout the year, they do not provide the full story. Equally important to price shape is the absolute price level in each month. One indicator of the market's expectation of the future price of electricity is the "forward curve," or the set of forward or futures contracts traded today for delivery of energy at some point in the future. The historical shape analysis can be combined with this current market view of future electricity prices to provide a "mark-to-market" fair market valuation of the shaped energy over the life of the PPA. Another important aspect missing from the P50 shapes discussed above is an indication of the level of uncertainty in generation and price in each month. The way in which this uncertainty is actualized over the life of a PPA can have a significant effect on overall value. As such, it is important to properly incorporate uncertainty in any assessment of contract value or risk.

In the first article in the series, we provided details on the mechanics of combining historical spot price analysis with current forward curves to inform PPA fair market value. We also discussed how a simulation-based approach can provide an understanding of uncertainty in both generation and price. In this article, we focus on the end results of the simulation-based analysis for determining PPA value and risk. In particular, we investigate various different granularities of shaped generation and the value and risk that different shape profiles impart to the contract.

Figure 2 below presents a breakdown of various different generation shape components that affect the fair market value of a renewable PPA. In order to isolate the true value of each shape component, both generation and market prices are considered at the same level of granularity when computing overall contract value. Moving from left to right along the x-axis in the charts, each successive shape scenario uses an increasingly granular methodology for aligning generation with price to value the PPA, and the incremental change in value at each successive step represents the fair market value for that particular shape component.

Figure 2

Average Value of Energy Generated for an Example Solar and Wind PPA in Texas under Various Shaping and Valuation Granularities

Notes: Each bar shows the incremental value to the PPA for a particular shape scenario. Simulations of market prices incorporated quotes for ERCOT North Hub real-time electricity futures contracts obtained from cmegroup.com as of June 22, 2018.

Source of image: cQuant.io ReAssure PPA®.

It is important to note that the value and risk of the various shape components can vary widely from location to location and as electricity price dynamics and grid topology evolve over time. To ensure all important locational parameters for a given renewable generation facility are captured and market dynamics are up-to-date, such an analysis should be performed periodically for each location in question. Additionally, the present analysis assumes that generation and market price dynamics are not directly coupled by any structural mechanism and the uncertainty in generation is assumed independent from the uncertainty in market prices. While this assumption is valid in markets with low to modest levels of renewable energy, significant structural relationships between renewable generation and market prices may develop in markets with deeper renewable penetration. In these cases, large concentrations of intermittent generation may have a material impact on electricity prices during periods of high production. A full analysis of the implications of such structural relationships, sometimes referred to as "renewable penetration risk," is outside the scope of the present discussion.

Baseload Valuation

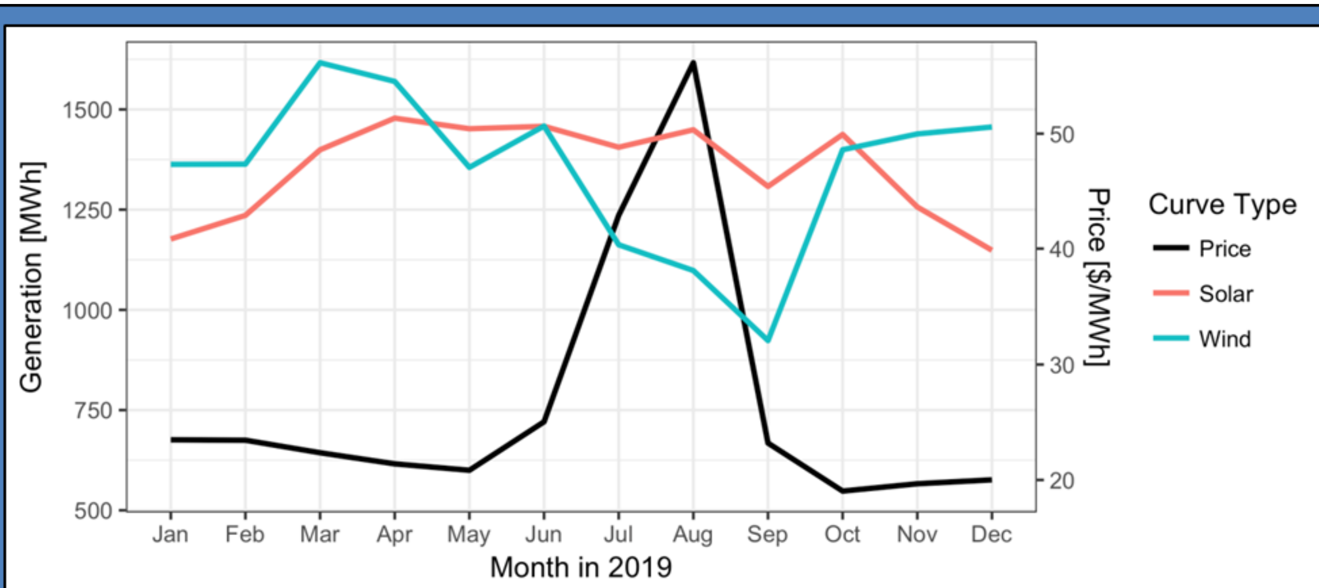
The Baseload scenario in Figure 2 assumes the same volume of energy is guaranteed over every hour of the year and uses a single average annual price to value this energy. This is the coarsest shape one could achieve for the energy under a PPA and also the coarsest approach one could take to value that energy. The hourly shaped quantity is simply the expected total annual energy for a single year divided by the number of hours in that year, and the fair market value is the average around-the-clock (ATC or 7x24) forward contract price over the year, weighted by the number of hours in each month. As Figure 1 clearly shows, in reality there is significant seasonal and hourly variation in both generation and price. Nonetheless, the Baseload valuation approach does capture a majority of the PPA's value by accounting for the average hourly generation and the average price that generation would receive in the market.

Flat Monthly Valuation

Recognizing that the Baseload approach provides far too coarse a view of value, the Flat Monthly scenario shapes both generation and price by calendar month. This valuation approach incorporates seasonal effects by using the monthly forward contract prices for electricity and weighting these prices by the expected renewable generation in each corresponding month. That is, the flat monthly shape guarantees delivery of a fixed quantity of energy in each hour of a given month, though this quantity does vary month-to-month to account for seasonal effects. This shaping and valuation approach results in a small increase in overall PPA value for solar and a slight decrease in value for wind. The overall direction of the incremental change compared to the Baseload scenario is determined by the seasonal alignment of generation and price. This impact is positive for solar and negative for wind generation, consistent with seasonal production characteristics and the term structure of prices for ERCOT North Hub in the summer months.

Figure 3 on the next page provides a more detailed view of the seasonal fluctuations in expected generation and price for the year 2019. Seasonal generation and price alignment is marginally coincident for solar, corresponding to a slight incremental increase in seasonally-weighted value compared to the Baseload scenario, as seen in Figure 2. For wind, seasonal generation and prices are somewhat anti-coincident, yielding a small loss in value over the Baseload shape scenario. In either case, the change in value from the baseload case is relatively small, indicating that seasonal effects are "averaged out" relatively well when taking a coarser annual view. Again, the result presented here is very location-specific; seasonal generation and price shapes may have different or more significant effects on PPA fair market value in other areas of the country due to differing weather and price dynamics.

Figure 3
2019 Monthly Expected Generation and Around-the-Clock (ATC) Forward Contract Prices



Note: Solar and wind display somewhat reversed seasonal trends, with solar peaking in the spring and summer and wind peaking in the winter and early spring. The solar facility represented in the figure is assumed to be a fixed array with a tilt angle optimized to maximize expected total annual energy production.

P50 Hourly Valuation by Month

Further increasing the granularity of the generation and price shaping, the P50 Hourly scenario values the PPA by aligning the median hourly generation and price shapes in each month of the year.[4] In addition to capturing seasonal changes in monthly aggregate generation and price levels, this methodology also captures the important hourly shapes illustrated in Figure 1, including the variation in hourly shape from month to month. Figure 2 shows that incorporating the hourly shapes into the valuation significantly affects fair market value for both solar and wind PPAs. Essentially, hourly shaping provides a more granular view of the intra-day alignment of generation with price. This results in a significant refinement in the weighting assigned to the market value of shaped generation in each hour compared to the Baseload and Flat Monthly scenarios.

The P50 Hourly valuation scenario differs fundamentally from the Baseload and Flat Monthly scenarios, which both include a guaranteed shaped amount of energy that does not fluctuate throughout a given day. A flat hourly energy shape is clearly misaligned with solar generation, which will always be zero during the nighttime hours when the sun is not shining. Moreover, the very hours in which solar does not generate tend to exhibit the lowest electricity prices, so overall PPA value will tend to be reduced by any shape that guarantees delivery over these hours.

Using the P50 Hourly profiles to shape the contract yields a guaranteed delivery profile that is much more consistent with actual solar production and emphasizes the natural alignment of solar generation with higher market prices during the peak hours of the day. This improved alignment in generation and price contributes an incremental increase in solar PPA value of more than 10% over the Flat Monthly valuation approach, as seen in Figure 2.

In contrast to solar, wind tends to show elevated generation during hours of the day when prices are low, as discussed above and shown in Figure 1. This anti-coincidence with price contributes an incremental decrease in wind PPA value for the P50 Hourly scenario compared with the Flat Monthly scenario. It is important that both the buyer and seller understand the negative incremental value of the hourly wind shaping with respect to price; over the life of a five-year 10 MW PPA, the almost $1.40/MWh reduction in the P50 Hourly shaped value of wind energy seen in Figure 2 translates to over $500 thousand in total value loss relative to the Flat Monthly scenario.

Full Stochastic Valuation and the Value of Uncertainty

The final shape scenario shown in Figure 2 uses a Full Stochastic valuation to simulate generation and prices and determine the true value of uncertainty around the shaped hourly P50 profiles. This value of uncertainty is akin to "extrinsic value" in the context of options theory or thermal generation asset valuation. The Full Stochastic valuation scenario represents an unshaped PPA, or what is often referred to as "unit contingent" or "as produced" in contracting terminology. That is, no guarantee is made by the seller about the energy produced under the PPA on any timescale.[5] In this case, the buyer assumes both the generation and price risk and takes whatever energy is produced by his full or prorated share of the facility. In some cases, the nature of the distributions of price and generation is such that the added uncertainty may actually contribute significant value to the contract, on average. This is particularly true when distributions of either generation or price (or both) are strongly positively skewed. Indeed, for both the solar and wind facilities analyzed in the present example, the uncertainty in generation and price actually comprises the second-largest component of total value for the contract, as seen in the right-most column of the solar and wind plots in Figure 2.

The ERCOT electricity market, in particular, is notorious for large price spikes during periods when the grid is strained due to extreme hot or cold weather (as covered in O'Neill (2017)), or when unexpected outages force significant portions of the generation stack out of operation. These price spikes result from "scarcity pricing," a market mechanism whereby a large premium may be paid for energy generated during periods of low resource availability.[6] The result of this dynamic is that the distribution of historical ERCOT real-time prices is anything but normal, with an extreme positive skew and large excess kurtosis. For the historical ERCOT North Hub real-time hourly dataset used in the present analysis, the raw data showed a skewness of 33.5 and an excess kurtosis of almost 1400, whereas a normal distribution would have values of zero in both cases. The main point here is that the ERCOT North Hub shows an extremely significant directional shape in the uncertainty around expected prices, and this shape has a material effect on the valuation of energy flows within that market. The Full Stochastic valuation scenario accounts for this uncertainty shape, placing a dollar-per-megawatt-hour value on the combined uncertainty from both generation and market electricity prices for the contract.

In the case of the solar PPA in our example, the uncertainty in generation and price adds an additional $3.41/MWh to the value of the PPA above the P50 Hourly scenario. For wind, the incremental value is even greater at $6.39/MWh. In both cases, the mechanism driving the additional value is that both wind and solar may be generating during periods when the grid is strained and prices spike to extremely high levels. The difference between the value of uncertainty for solar and wind is primarily driven by the amount of uncertainty in the generation itself, as well as its alignment with price uncertainty. Wind generation tends to be more uncertain hour-to-hour than solar, and uncertainty peaks during summer months when market prices are also highly volatile and likely to undergo very high spikes. Even though expected wind generation dips in the summer months, the variability around this expected generation aligns well with the potential for very high prices; the net result is a significant positive $/MWh value of the uncertainty around expected generation and price.

Solar shares in this value, though to a lesser extent, since its hour-to-hour generation is less variable than wind and its seasonal profile already expects high generation in the summer months. Essentially, there is less upside potential for summer solar generation than there is for summer wind generation, and the occasional alignment in generation upside with large price spikes results in a disproportionate increase in value relative to the mean. The bars for the Full Stochastic scenario in Figure 2 illustrate the contribution of uncertainty to overall PPA value. For solar, the value of uncertainty makes up about 11% of total PPA value, while for wind it is an even higher proportion at roughly 21%. As the plots show, a proper understanding of the value of uncertainty in renewable PPAs can be absolutely critical to an accurate valuation of the contract. In the case of a five-year 10 MW wind PPA, the $6.39/MWh value of uncertainty observed in this example would translate to over $2.5 million in expected generation value over the contract lifetime.

While the analysis presented here does indicate a significant value contribution from uncertainty around the P50 shape, it should be noted that the unit-contingent or “as produced” contract type modeled by the Full Stochastic valuation scenario also involves more risk to the buyer than the various shaped deals. This is because the buyer accepts the generation risk in a unit-contingent contract whereas he is guaranteed a generation shape in the others. That is, while the added uncertainty may contribute additional value at the mean, the buyer is taking on a greater risk to access that value and must accept greater downside potential as well. Moreover, the fact that there is no guarantee of generation volumes means the unit-contingent contract is more difficult to hedge using standard financial products, as discussed in the following sections. In general, a PPA buyer should be aware of the full spectrum of risk before entering into any PPA, and he should have a plan in place to monitor and mitigate some of the long-term risks associated with the contract as market dynamics evolve.

Hedging Renewable PPAs

In the previous section we identified how various different shape granularities—Baseload, Flat Monthly, P50 Hourly, and Full Stochastic—contribute value to wind and solar PPAs in central Texas. However, restricting the granularity of the prices used to value a shaped PPA, as done above, is a somewhat artificial construct useful primarily for its ability to isolate the individual value contribution of each shape component. In practice one should always use a full stochastic simulation-based approach to value a PPA regardless of its contracted shape. That is, even if the PPA were contracted to include a baseload guaranteed shape of energy, a proper valuation should incorporate a robust understanding of the uncertainty in generation and price around the contracted quantity. The amount of residual (or deficit) energy between the contracted shape and the realized generation volume contributes risk to the seller's position in a shaped PPA and should be valued within this context.

In this section, we shift our focus from value to risk, examining cash flow uncertainty around renewable PPAs from both the buyer and seller's perspectives and exploring some strategies to mitigate this uncertainty. To simplify discussion, we consider contracts for two of the shape scenarios discussed above: one baseload shape for the same fixed number of MWh in every hour of the year and one shaped by the P50 hourly generation profile in each calendar month. We simulate settlement of these two contracts for the month of August 2019, consistent with the price simulations used to value the various shape scenarios above, and we demonstrate how a stochastic analysis can be used by both PPA buyers and sellers to design optimal hedges custom-tailored to a particular contract. We have selected the month of August because it typically contains a large amount of uncertainty in the ERCOT electricity market; however, the analysis presented here can be generalized and performed for all months of a PPA's horizon to design a hedging program that covers the entire contract.

Settlement Amounts Including Hedge Payoffs

As discussed above, the buyer and seller bear fundamentally different risks when entering into a shaped PPA. Because of the shape guarantee, the buyer is exposed only to price risk while the seller is exposed to both price and generation risk. As such, hedging programs should be designed with a thorough understanding of each counterparty's specific risk profile, appetite for risk, and primary objectives for entering into the PPA. While a comprehensive discussion of hedge program design is outside the scope of this article, we present examples that make use of around-the-clock (ATC) forward contract hedges enacted at the time of PPA signing.[7] The methodology we develop below can also be used to hedge PPAs using more advanced financial instruments and/or structured transactions and to layer risk-reduction programs onto an existing PPA after contract signing.

In the broadest sense, a hedge is a physical or financial position taken to reduce uncertainty in portfolio returns or cash flows. An effectively hedged portfolio contains multiple components where losses in one component are at least partially offset by gains in another. The general idea of offsetting returns is related to the concept of diversification from modern portfolio theory. Because of the availability of a number of financial derivative products designed specifically for the purpose of hedging energy positions, it is often easier to achieve a diversification effect in energy portfolios than it may be in portfolios of stocks. To hedge a given position, one may simply take an opposing position in a derivative contract that is similar in delivery volume, timing, and location.[8] The most common of these energy derivatives are swaps, forward contracts, futures contracts, and European options. Each of these, while they differ slightly in their exact contract specifications and settlement procedures, entitles the holder to buy or sell a pre-specified quantity of energy or other commodity at a pre-specified price at some point in the future.

For someone with an expected long future exposure in the spot market, taking a short position in a swap for the same commodity will replace exposure to the variable spot price with exposure to the fixed contract price at delivery. That is, it will "swap" a fixed price exposure for the native variable price exposure. This has the effect of reducing variability in the cash flows during the delivery period, and the magnitude of the reduction is proportional to the magnitude of the volume contracted in the swap. Essentially, by selling the swap, the seller is "locking in" the contracted price of the swap instead of remaining exposed to the uncertain future price in the spot market.

The Buyer's Position

From the above explanation of hedge implementation, it is clear that the variability in hedged portfolio returns is dependent on the quantity hedged. In the context of renewable PPAs, we define the hedge ratio, r, to be the ratio of the volume contracted in a hedge position to the expected volume in the native PPA position. For example, if a PPA is expected to deliver 1000 MWh in a given month and the buyer sells 300 MWh in a forward contract, this would correspond to a hedge ratio of 0.3. Using this definition, suppose a buyer of a baseload PPA decides to hedge his settlement amounts in a particular month by selling a swap at a price F for some ratio r of his guaranteed hourly generation quantity. We assume the price of the swap is equal to the average simulated price of power in the delivery month; this corresponds to the PPA and hedge valuations being effectively marked-to-market against the same forward curve. In practice, this would occur if the hedges were enacted at the time of PPA signing.

Because the contracted baseload generation from the PPA does not vary by hour, we modify the notation used in equation 1 and denote the fixed hourly generation quantity by G, dropping the dependence on time. Expanding the right-hand-side of equation 1 and including the payoff from the hedge, the hourly hedged settlement amounts for the buyer of a baseload PPA are given by

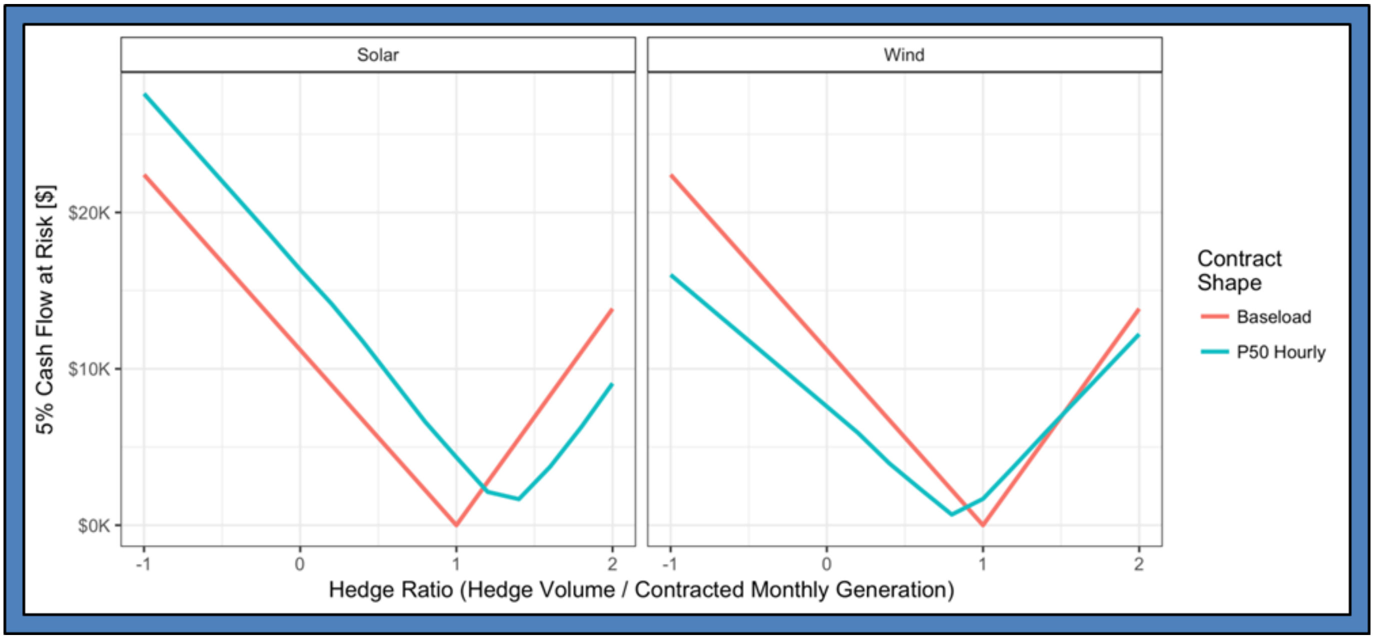
$$\begin{aligned} \boldsymbol{A_{buy}}(\boldsymbol{h}) &= G\boldsymbol{p}(\boldsymbol{h}) - GK - rG[\boldsymbol{p}(\boldsymbol{h}) - F] \# (5) \\ &= G\boldsymbol{p}(\boldsymbol{h})(1-r) - G(K - rF), \end{aligned}$$

where F is the contracted per-unit price of the swap and all other notation is as described in equations 1-3. The final term in the first line represents the hedge payoff in hour h. After rearranging terms to yield the second line in the equation, the only term that contains a quantity not known at the time of contract signing is the first, $G\boldsymbol{p}(\boldsymbol{h})(1-r)$. This term represents the real-time market value of the unhedged portion of the contracted generation, G, in hour h; notably, it vanishes when $r = 1$. That is, when the entire contracted generation quantity is sold forward, the hedge is "perfect" and the buyer bears no risk for the PPA. In this case, the settlement amount in each hour is constant and given by $G(F - K)$. When the buyer is able to sell a swap on the forward market for more than the contracted PPA price, K, this corresponds to a guaranteed profit in each hour of the hedged delivery period.

For the case of a PPA shaped by the P50 hourly profile in each month of the year, the calculation is similar. However, in this case, the hedge ratio must be computed against total monthly contracted generation since the guaranteed shape under the PPA, $G(h)$, varies by hour. Using an ATC swap to hedge some fraction of the total monthly contracted generation will incur marginal "slippage," or misalignment between the hedge payoff and the unhedged PPA settlement amount. More sophisticated hedging programs can be developed to minimize slippage and maximize hedge performance; nonetheless, a significant risk reduction can still be achieved using ATC swaps.

Figure 4

Buyer's August 2019 Cash Flow at Risk (CFaR) for 10 MW Shaped Solar (left) and Wind (right) PPAs as a Function of Hedge Ratio



Notes: A hedge ratio of 1.0 corresponds to selling a swap for 100% of the shaped generation volume in the delivery month. Note that the baseload contract is perfectly hedged by selling a swap for full monthly generation volume; in this case, the CFaR is identically zero.

Source of image: cQuant.io ReAssure PPA®.

Figure 4 shows the simulated 5% cash flow at risk (CFaR) for August 2019 for a portfolio containing a long position in a 10 MW PPA and a short swap contracted at various different hedge ratios. The CFaR is computed as the difference between the simulated expected monthly portfolio settlement amount and the simulated P5 settlement amount. Consistent with the theory presented above, the plot shows that the Baseload contracts for both solar and wind (red lines in the figure) are perfectly hedged when 100% of the contracted generation is sold on the forward market. In this case, the CFaR for both the solar and wind PPAs drops to exactly zero and the buyer has a guaranteed profit for each contracted MWh in the amount of the spread between the contract price of the swap, F, and that of the PPA, K.

For the solar and wind PPAs shaped by the P50 hourly generation profile, the CFaR never quite reaches zero for any hedge ratio, though the plots show it can be reduced dramatically from the unhedged case. The optimal hedge ratio for each P50 hourly shaped PPA is the value that corresponds to the lowest point on the blue curve in each of the plots. Interestingly, the optimal hedge quantity is actually greater than one for the solar PPA. This means that the optimal hedge is to sell more than the monthly guaranteed generation under the contract. This seemingly counterintuitive result occurs because the financial product used to hedge the PPA is a short ATC swap, so the hourly hedge volumes are out of alignment with the hourly shaped generation profile of the PPA. This misalignment, in conjunction with the uncertainty in realized generation at the hourly level, creates slippage in the hedge. The result is a distortion of the P50 Hourly CFaR's approach to optimality away from the Baseload case where PPA and hedge volumes align perfectly in each hour.

The interpretation here is that each MWh sold forward in the swap provides slightly less portfolio CFaR reduction than the risk that one MWh of generation under the PPA creates. Thus, more MWh must be sold in the hedge than generated under the PPA in order to minimize risk for the contract. The opposite is true for the wind PPA where the optimal hedge ratio is slightly less than one. This indicates that, up to the optimal hedge quantity, each additional MWh in the hedge provides a slightly greater reduction in risk than the amount that one additional MWh of generation under the PPA would add. In either case, the main takeaway is that the buyer's position in a shaped PPA is relatively straightforward to hedge using standard financial products.[9]

The Seller's Position

Compared to the buyer's position, the seller's risk exposure in a shaped PPA is significantly more complex and contains nuanced interactions between generation and price risk. In addition, these two risk factors cannot be entirely separated, and so must be hedged simultaneously. This becomes clear when looking at the equation for the seller's hourly hedged settlement amount. We again begin by considering settlement amounts for a Baseload shaped PPA, and we assume the seller hedges his native short position with a long ATC swap. Using the notation in equation 4 and adding the swap payoff, the seller's hedged hourly settlement amounts are given by the following equation:

$$\boldsymbol{A_{sell}}(\boldsymbol{h}) = GK + \boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h}) - G\boldsymbol{p}(\boldsymbol{h}) + rG[\boldsymbol{p}(\boldsymbol{h}) - F]. \#(6)$$

Again, $\boldsymbol{g}(\boldsymbol{h})$ is the actual generation of the facility in hour h, F is the per-unit price of the swap, and we have omitted any explicit dependence on time for the hourly guaranteed quantity, G, since it is the same in all hours under the Baseload contract. The final term in the equation represents the hedge payoff in hour h.

Some minor rearrangement of equation 6 yields a form that is more amenable to discussion:

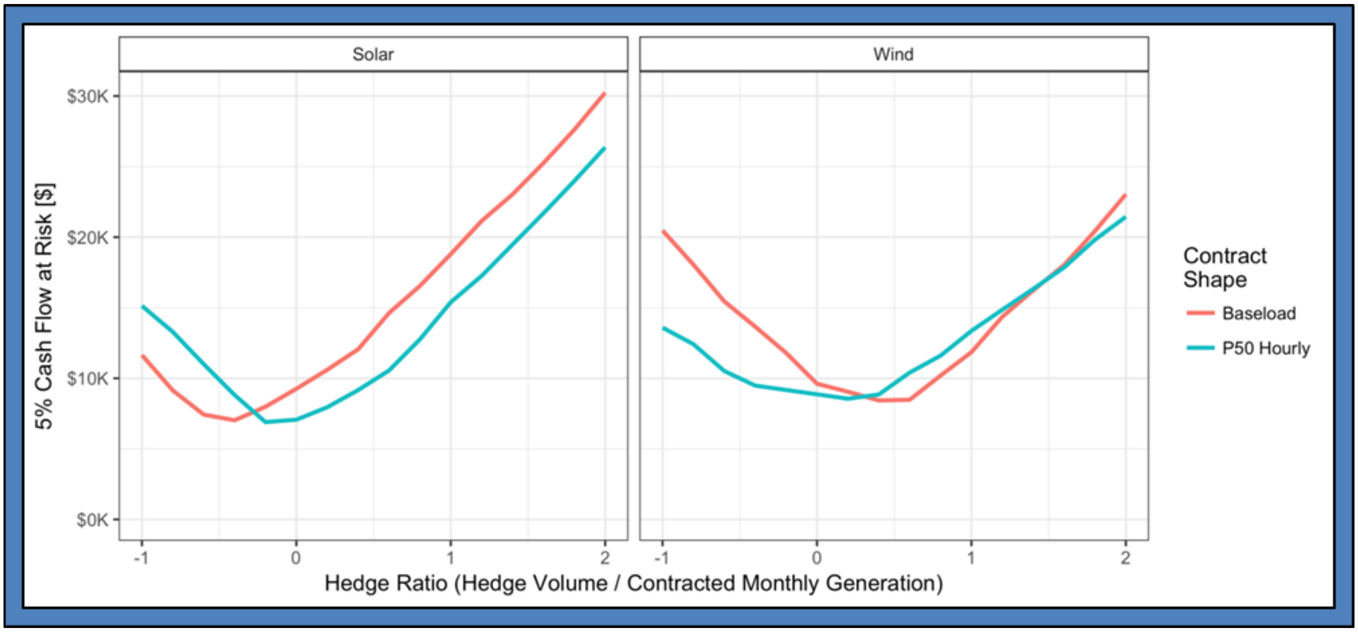
$$\boldsymbol{A_{sell}}(\boldsymbol{h}) = G\big[K - [rF + \boldsymbol{p}(\boldsymbol{h})(1 - r)]\big] + \boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h}). \#(7)$$

Disassembly of this equation tells us a number of interesting things about the seller's risk profile. First, we note that when the swap price is equal to the PPA price ($F = K$) and the hedge ratio is 100% ($r = 1$), the seller's settlement amount simplifies to $\boldsymbol{A_{sell}}(\boldsymbol{h}) = \boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h})$, which represents the hourly real-time market value of unit-contingent generation. That is, when the contract price of the swap is equal to the PPA price and the seller hedges 100% of the monthly quantity, his risk exposure is the same as if he were liquidating all production under the PPA directly into the market as-produced. Figure 5 on the next page shows that, in this case, the seller has significantly more risk than in the unhedged case where $r = 0$. This is logical since selling all generation directly into the market as-produced exposes the seller to the full amount of both generation and price risk as well as the magnifying effect of their dynamic interaction. Thus, the PPA itself is a hedge for the seller against his native exposure of renewable generation to real-time electricity prices.

Secondly, the terms inside the outermost pair of square brackets in equation 7 describe the interaction between the PPA price, K, and the value of the shaped energy, G. The total value of shaped energy is determined by the forward market price at the time the hedge is enacted, Fr, and the spot market at delivery, $\boldsymbol{p}(\boldsymbol{h})(1 - r)$. The hedge ratio, r, acts as a risk transfer coefficient, modulating price exposure for the shaped energy between the forward and spot markets. When $r = 1$, the value of the shaped energy in this term is determined entirely by the forward price, F. When $r = 0$, the value is determined entirely by the spot price at delivery, $\boldsymbol{p}(\boldsymbol{h})$, which is the native position without any hedge at all. For values of r between zero and one, value (and risk) is transferred from the spot to the forward market. The practical meaning of this term is that if the forward market moves downward, increasing the hedge ratio by buying additional swaps allows the PPA seller to lock in additional value for the shaped generation amount.

While exploring limiting cases of equation 7 is instructive to build an intuitive understanding of the value and risk in the seller's position, the nonlinear term, $\boldsymbol{g}(\boldsymbol{h})\boldsymbol{p}(\boldsymbol{h})$, makes it impossible to describe the optimal hedge ratio using a closed-form equation. Both the future generation, $\boldsymbol{g}(\boldsymbol{h})$, and the future electricity price, $\boldsymbol{p}(\boldsymbol{h})$, are random variables with distributions that can only be understood empirically. Their product is an even more complex tangle of uncertainty that can only be accessed prior to delivery via numerical simulation. To this end, Figure 5 shows the seller's simulated CFaR as a function of hedge ratio for the same solar and wind PPAs as in Figure 4.

Figure 5
Seller's August 2019 Cash Flow at Risk (CFaR) for 10 MW Shaped Solar (left) and Wind (right) PPAs as a Function of Hedge Ratio



Note: A hedge ratio of 1.0 corresponds to buying a swap for 100% of the shaped generation volume in the delivery month.

Source of image: cQuant.io ReAssure PPA®.

The complicated nature of the seller's risk profile can be seen in the complexity of the curves. Even for the baseload contract shape, the CFaR's approach to optimality (the minimum point on the curve) is far from linear, as it was for the buyer. In all cases, the optimal hedge ratio is far from 100% of the shaped monthly generation; in fact, it is actually negative for solar, indicating a short position should be taken in the swap rather than a long position. We discuss this in more detail below. Finally, it is important to note that the seller's CFaR remains relatively high even when the optimal hedge ratio is used to mitigate the seller's risk for the PPA. Depending on the type of shaping, the best risk reduction the seller can expect using an ATC swap is about a 30% drop in CFaR; in the case of P50 Hourly shaped solar and wind PPAs, the risk reduction is almost nonexistent using this particular financial instrument. This is an indication that more sophisticated hedging schemes and financial products are needed to effectively reduce the seller's risk in these PPAs.

The fact that the optimal hedge ratio for a seller of a baseload solar PPA represents a sale of even more energy on the forward market may appear somewhat counterintuitive initially. The explanation is related to the misalignment of actual solar generation during the delivery month and the guaranteed shape of the PPA. Because of the baseload shape, the seller guarantees the buyer energy during a large number of hours at night when the sun is not shining. During these hours, he must purchase sufficient energy from the spot or forward market to satisfy his contractual obligation to deliver the baseload shape under the PPA.[10] In these nighttime hours, the PPA seller's native position in the spot market flips from long to short; thus, the natural hedge to transfer his spot market exposure to the forward market is to short-sell a swap.

When the seller of the PPA further sells an ATC swap on top of his native short position, he effectively transfers some long exposure to on-peak prices to a corresponding amount of short exposure to off-peak prices. That is, the hedge reduces some of the seller's long spot market exposure in the extremely volatile on-peak hours when the solar facility is likely to be generating above the guaranteed baseload amount. In exchange, the hedge increases the seller's short position in the off-peak hours, requiring him to buy back even more energy from the spot market during these hours to satisfy his obligation to deliver the baseload energy shape. However, because off-peak prices are so much less volatile (uncertain) than on-peak prices, the net result of the hedge is an overall reduction in CFaR for the seller's monthly settlement cash flows. Essentially, the seller is able to gain an overall reduction in cash flow uncertainty by using a short ATC swap to shift a portion of his risk from the on-peak to the off-peak period. This shift in risk comes with a corresponding change in position for the shifted energy during hours when the solar facility's generation is insufficient to satisfy the baseload shape requirement.

Conclusions

The recent increase in adoption of renewable PPAs by a broadening range of market participants has been accompanied by a corresponding increase in the sophistication of these contracts. Some innovative new PPA structures have focused on contractually shaping the delivered energy rather than forcing the buyer to accept both the generation and price risk for the renewable generation. In turn, these new contract structures have opened the door for new strategies to reduce risk for both the buyer and the seller.

In this second article in a two-part series on renewable PPA analytics, valuation, and risk assessment, we discussed how PPA value is built up from interactions between generation and price at the annual, monthly, and hourly level. We also demonstrated how uncertainty in both realized renewable generation and the real-time market price of electricity can have a significant effect on contract value, and how to compute this value through data-driven contract-specific analysis. Building on the discussion of contract shaping, we presented a practical methodology for buyers and sellers to consider how they can hedge their risk(s) in renewable PPAs. We demonstrated that for a particular contract structure at a particular location, we can derive optimal hedge quantities that minimize cash flow at risk for monthly settlement amounts with regard to generation and price risk.

While the present discussion has attempted to provide an introduction to the concepts of shaping and hedging for renewable PPAs, it is far from a comprehensive treatment of the subject. It outlines a set of analytical methodologies that can be leveraged by both buyers and sellers of PPAs to understand value and risk within the contracts and to take action to mitigate risks and prevent loss of value. The methods discussed here can be applied to arbitrary contracted energy shapes and a broad set of hedge instruments. As such, the analysis can be used to generate a detailed understanding of the interplay between the physical energy generated under the PPA and the financial value of that energy within a broader portfolio context and amid complex and volatile energy markets.

Endnotes

1 The first article in the series, entitled "Lifting the Veil on Hidden Risk in Renewable Power Purchase Agreements," provides a more thorough background on renewable PPAs in general and best practices for valuation and risk assessment. The article is on pages 29 to 44 of the Summer 2018 edition of the *GCARD*, which is publicly available and can be downloaded at the following URL: http://www.jpmcc-gcard.com/wp-content/uploads/2018/05/GCARD-Summer-2018.pdf.

2 The terms, contract for differences (CFD), virtual PPA, and synthetic PPA all refer to the same contract structure and may be used interchangeably.

3 Our approach to simulating prices and generation follows the methodology outlined in the first article in this two-part series. Please see "Lifting the Veil on Hidden Risk in Renewable Power Purchase Agreements" in the Summer 2018 edition of the *GCARD*.

4 In practice, if generation is contracted at a particular quantile, it is typically the P99 rather than the P50 (median). The P99 hourly shape provides 99% confidence that the renewable facility will generate at least the shaped amount of energy in each hour. Using the P99 shape gives financiers more confidence that the contracted generation will be produced by the facility and the seller will not have to go to market to make up a deficit, which would create additional risk in the contract. Here we use the P50 because it is a more central statistic and aligns better with our goal of isolating the incremental PPA value of different shaping granularities.

5 Unit-contingent contracts do often include a mechanical availability guarantee in place of a shape guarantee. The availability guarantee removes some or all of the risk to the buyer of mechanical failures or other non-weather-related production deficiencies that may occur throughout the life of the contract. Valuing such an availability guarantee is outside the scope of this article and depends on the probability of incurring an insurable loss in addition to the dynamics of real-time energy generation and market dynamics.

6 A fear of scarcity pricing may even be seen within the forward and futures markets in ERCOT. In the first quarter of 2018, the forward contract for delivery of August 2018 ERCOT North Hub on-peak power traded above \$200/MWh in response to announcements of retiring baseload capacity and forecasts of thin summer reserve margins. As of the time this article was written, the average realized real-time price during on-peak hours in the August delivery month was just over \$43/MWh. This indicates that the price spike in the forward market may have been largely driven by fear of a possible scarcity pricing event that never materialized.

7 The ATC forward contracts used in the example are assumed to deliver the same quantity in all hours of the delivery month. In practice, on- and off-peak financial products are more actively traded than ATC products. The on- and off-peak periods are defined by trading conventions in the markets where the contracts deliver energy. For example, forward contracts for on-peak power at ERCOT North Hub, as quoted by CME Group, deliver during hours-ending 0700-2200 Monday through Friday, excluding North American Electric Reliability Corporation holidays. Here we have used around-the-clock contracts simply to condense discussion. Please see the following link for additional details on the CME ERCOT North on-peak futures contract and current quoted prices: https://www.cmegroup.com/trading/energy/electricity/ercot-north-zone-mcpe-5-mw-peak-swap-futures.html.

8 In practice, most hedges will incur some degree of basis risk, shape risk, counterparty credit risk, and/or other risks due to imperfect alignment between the native portfolio position and the actively-traded derivative contracts available to hedge it. While these risks too can be mitigated, a thorough discussion of these nuances is outside the scope of the current discussion.

9 The analysis here does not consider margin call risk incurred by exchange-traded futures contract positions, counterparty credit risk incurred by positions in over-the-counter forward contracts, or other risks related to the hedge positions themselves. These risks should be considered within a holistic view of a PPA hedging program.

10 In practice, sellers of a shaped PPA will not typically maintain a short position over the life of the contract. They will either hedge this position in the forward market or will contract for firming and shaping with third-party market participants.

Reference

O'Neill, P., 2017, "Fear and Heat in the Texas Power Markets: A Tail-Risk Example and Perspective," *Global Commodities Applied Research Digest*, Editorial Advisory Board Commentaries, Vol. 2, No. 1, Spring, pp. 101-111.

Author Biographies

BROCK MOSOVSKY, Ph.D.
Director of Operations and Analytics, cQuant.io

Dr. Brock Mosovsky is Co-Founder and Director of Operations and Analytics at cQuant.io, a leading software-as-a-service provider of energy-focused advanced quantitative analytics. He has over a decade of analytical modeling experience with a focus on risk management, asset valuation, financial engineering, and model validation for the energy industry. Dr. Mosovsky has worked with the country's largest electric utilities and independent power producers to help improve operational and budget certainty amid volatile financial energy markets and has built and validated financial models for more than 100 gigawatts of nameplate generation capacity. He is also an experienced advisor on valuation and risk assessment of structured transactions and exotic derivatives including asset-specific revenue put options, heat rate call options, and complex power purchase and tolling agreements.

Dr. Mosovsky holds a Ph.D. in Applied Mathematics from the University of Colorado Boulder, a B.S./M.A. in Mathematics from Villanova University, and was awarded a U.S. Fulbright Scholarship for study in the Netherlands.

LANCE TITUS
Managing Director, Uniper Global Commodities

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

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

The Superclasses of Assets Revisited

Robert Greer
Scholar-in-Residence, J.P. Morgan Center for Commodities (JPMCC), University of Colorado Denver Business School; and Member of the JPMCC's Research Council

Mr. Robert Greer, Scholar-in-Residence at the JPMCC, presenting at the December 4, 2015 JPMCC Research Council meeting. Mr. Greer is a member of the JPMCC's Research Council, its Advisory Council, and the *GCARD*'s Editorial Advisory Board.

Over 20 years ago I published a paper that is still referenced today regarding the definition of an investable asset class. ("What is an Asset Class, Anyway?" *Journal of Portfolio Management*, Winter 1997). This current paper will summarize that earlier work, since it is still relevant, but will also build on that work to address another issue important to investors – how "irrational exuberance" affects various asset classes.

The original article defined an asset class as "a set of assets that bear some fundamental economic similarities to each other, and that have characteristics that make them distinct from other assets that are not part of that class." With 20 years of hindsight I would now add that we are talking about investable assets. I would also say that the assets in a class have certain similar risk factors that distinguish them from other <u>investable</u> assets. Note that this definition does not require that one asset class has a low correlation with another distinct asset class, nor does it require that the individual assets within an asset class be highly correlated to each other; rather, it looks at the underlying fundamental drivers of changes in price of an asset.

In some cases, derivatives are required to make an asset class investable, or are used to give exposure to the risk factors of an asset. For instance, a stock option is a derivative that can give exposure to price movements of a basic asset class, a share of stock. (Some may argue that the share of stock is itself an investable derivative which gives exposure to the actual assets owned by a corporation.) In a similar vein, a commodity futures contract is a derivative that gives an investor exposure to the actual physical commodity referenced by the contract. (Note: it is the commodity itself that determines membership in an asset class, not the futures contract. Futures contracts on corn and oil would belong to a different asset class than futures contracts on the S&P 500.)

Using this definition, there are broadly three *superclasses* of assets, each of which will be discussed in turn:

- Capital Assets
- Consumable/Transformable Assets ("C/T Assets")
- Store of Value Assets ("SOV Assets")

Each of these superclasses can be divided into sectors, which some people call separate asset classes. For instance, many consider stocks and bonds to be two different assets. Also, some assets have characteristics of more than one superclass – gold has some characteristics of a C/T asset, and some characteristics of an SOV asset.

Capital Assets

A capital asset is an <u>ongoing</u> source of something of value. One of the most well-known capital assets is stocks. They provide the expectation of a stream of dividends for an indefinite period of time. The other well-known set of capital assets is bonds, which provide the expectation of a stream of interest payments, ending with the return of principal. At a higher level, both stocks and bonds could be viewed as derivatives that provide access to the assets of a corporation, with differing claims on those assets. But in any event, both stocks and bonds provide a stream of monetary rewards, and the value of a stock or bond might thus be assessed by using a discounted cash flow model to determine a net present value. This also means that, everything else being equal (which it really never is), the value of a capital asset will decline as the investor's discount rate increases. This is the unifying characteristic of capital assets – they can be valued using a discounted cash flow model, and are subject to changes in investor discount rates.

Using this framework, it should be clear that income-producing real estate is also in the capital asset superclass. So are foreign debt and equity instruments. But since each of these other capital assets also provides exposure to some unique risk factors as well, it can make sense for a portfolio manager to consider subsets of this generalized asset superclass.

Mr. Robert Greer, who is also a Senior Advisor at CoreCommodity Management, responds to a question from Ms. Amy Myers Jaffe (microphone), whom in turn is currently the Senior Fellow for Energy and the Environment at the Council on Foreign Relations. To Mr. Greer's left (in the photo) is Dr. Bluford Putnam, Ph.D., Chief Economist at the CME Group while to Ms. Jaffe's left (in the photo) is Dr. David Hammond, Ph.D., of the Hammond International Group. Both Dr. Putnam and Dr. Hammond are members of the JPMCC's Research Council.

Consumable/Transformable ("C/T") Assets

To quote my earlier paper, "You can consume it. You can transform it into another asset. It has economic value. But it does not yield an *ongoing stream of value*." That is a functional definition of a superclass of investable assets that does not include stocks or bonds. The best known of these C/T assets are physical commodities – "stuff" like oil, corn, cattle and copper. Some of these assets might be consumed directly (like cattle or corn), or some, like oil, might be transformed into an asset (gasoline) that can be consumed. These assets certainly have value, and that value is often accessed using the derivatives of commodity futures. But the asset, or its derivative, cannot be valued using a discounted cash flow model. Neither the commodity, nor its associated futures contract, generates an ongoing stream of value. It's no wonder that investable commodities, usually combined into an index to show the returns to the overall asset class, cannot be evaluated using the traditional tools of the Capital Asset Pricing Model – they aren't capital assets! A different model is used for valuing C/T assets – the model of supply and demand. While the specific risk factors determining the price of oil are different from those determining wheat prices, both of these assets are priced based on the generalized laws of supply and demand.

We do need to distinguish between the investable asset class of commodities and the well-known approach of "managed futures." Those managed futures typically utilize financial futures in addition to futures that give exposure to true commodities. Moreover, the actively managed futures account does not have consistent exposure to the direction of price movements in the underlying assets. At any given time, a managed futures account may have long exposure, short exposure, or no exposure at all to, say, the price of wheat. And at the same time that inconsistent exposure to the price of wheat and other commodities is typically mixed up with exposure to stock, bond, and currency values. So the best that can be said about managed futures is that, while they are not a C/T asset, they do provide exposure to the asset class of "gray matter" – if the trader is smart or has a good system, you might have good returns. But intellect is not an asset that can be bought or sold.

Store of Value ("SOV") Assets

The third superclass of investable assets is the Store of Value assets. They cannot be consumed. They cannot be valued using a discounted cash flow model. Yet they do have value. Fine art is an example of the SOV asset superclass. While it does provide some non-economic value, it is still "worth something." Currencies (distinct from debt or equity denominated in a foreign currency) is another example of where an investor may put his dollars (assuming the USD is his home currency) if he thinks that the foreign currency will appreciate relative to the dollar.

Significance for an Asset Manager

While there may be only three investable asset superclasses, there are certainly subsets of these classes, each with its own set of risk factors. Both stocks and bonds generate a stream of value, but some of the drivers of those streams of value are not the same. One is finite and the other has an indefinite life. Also bonds have a higher, though fixed, claim on assets of the issuing corporation. In a similar fashion, some of the drivers of supply and demand for oil are different from drivers of wheat prices. But there is one unifying driver of demand for all C/T assets – global economic growth. As global economies grow, they increase the demand for all C/T assets. This shared risk factor, along with the uniqueness of using a supply/demand model to consider valuations, sets the C/T assets apart from the other two superclasses.

There are also some investable assets that share characteristics of more than one superclass. Gold is "consumed" in the production of electronics and jewelry, some of which never re-enters the supply chain. But gold has even stronger characteristics of an SOV asset, useful when investors don't know where to turn for safety. Gold even has a little bit of a capital asset characteristic, to the extent that it can be leased. Undeveloped land is an example of an SOV asset which can be converted to a capital asset if it becomes part of an income-producing real estate project.

While an asset manager needs to go deeply into underlying risk factors in constructing a portfolio, and in considering the mix of risks offered in some of the hybrid assets mentioned, this framework of superclasses of assets can improve that manager's analysis. For instance, one would not try to use the

CAPM to value a C/T asset. This framework can also help an asset manager determine how much the portfolio is being exposed to the risk of irrational exuberance.

How do Superclasses Respond to Irrational Exuberance?

By "irrational exuberance," I mean the action seen too often with some investable assets, where there is not a trustworthy measure of "intrinsic value" and where investors consequently might bid up asset prices to unsustainable levels. For this phenomenon to occur, there must be a lack of an objective measure of value and also a constraint on supply. The tulip mania of the 17th Century is a classic case of speculators (I will not grace those market participants with the term "investor"), bidding for a limited supply of bulbs while the only measure of value was what they thought the next speculator might pay. A more recent case in our memory was the dot.com bubble of the late 1990s. There was no clearly recognized measure of value for many of those companies, but just a story. Yet there was, at least in the short term, a limited supply of dot.com shares available, so the stocks were bid to unsustainable levels until that bubble burst. Equities generally have these characteristics. There is a limited or constrained supply of the asset available, and no clearly objective measure of what those shares are worth.

Bonds are not nearly as subject to irrational exuberance. True, they exist in limited supply, so that unrealistic expectations might drive interest rate spreads to unrealistic levels, but at least bonds have a fixed maturity and, usually, a fixed schedule of interest payments, which can provide guardrails for valuations.

SOV assets, on the other hand, can in a major way be subject to irrational exuberance. As fear and greed flow through the markets, major shifts can occur in where it is best to "store value." Should it be in precious metals? Or in Treasuries? Or in the Swiss Franc? There is a limited supply of all of these assets and, again, they lack an objective measure of value.

C/T assets, specifically commodities, don't face the factors that lead to irrational exuberance, partly because investors, who are subject to that emotion, deal in the commodity futures markets rather than in trading physical commodities. This means that there is effectively no constraint on the supply of what an investor buys. If an investor wants to buy 200 contracts of crude oil, another market participant will take the other side of the transaction and immediately the market will have 200 more crude contracts than it did before. Granted, market participants may misjudge what the future price of crude, or coffee, or aluminum might be, but that incorrect judgement won't last for long. As the futures contract that they hold approaches the time of delivery, the futures price will converge to the price of the physical commodity, which is determined by supply and demand in the physical market. And that physical market does not for the most part include those investors/speculators that are bidding for futures contracts. Rather the supply and demand is driven by the actions of businesses that purchase the commodity for consumption or by consumers who are driving supply and demand by their actions in the grocery store or at the gas pump. Unlike capital assets or SOV assets, the commodity markets have an objective determinant of value that does not include those investors who might otherwise be subject to irrational exuberance.

Conclusion

This framework for defining asset classes should be helpful to portfolio managers who are making asset allocation decisions, including in commodities. It will help them achieve more balanced diversification and will also make them more aware of their portfolio risks – especially the risk of irrational exuberance.

Author Biography

ROBERT GREER
Scholar-in-Residence, J.P. Morgan Center for Commodities, University of Colorado Denver Business School

Mr. Robert Greer is the first person to define an investable commodity index and is a pioneer in explaining why commodity indexes are an asset class distinct from stocks and bonds. He developed one of the two common methods of explaining sources of commodity index returns and has spoken on this asset class on national television, at industry conferences and trade meetings globally, and at college lectures at Yale, Oxford, Columbia, Princeton and elsewhere. Mr. Greer spent eight years managing the commodity index businesses at Daiwa Securities, Chase Manhattan Bank, and J.P. Morgan before joining PIMCO in 2002 to build their inflation products business. Under his 13 years of leadership PIMCO's commodity business grew from a single pilot account to become the world's largest commodity investment management business, at one time responsible for $35 billion in accounts. During this time the other inflation strategies for which Mr. Greer had business responsibility, including inflation-linked bonds, real estate, and certain multi-asset strategies, also grew so that his lines of business included over $100 billion in assets under management.

Prior to building the commodity and inflation business for PIMCO and others, Mr. Greer spent a decade in the commercial real estate industry, and also spent many years in corporate finance and computer systems development. But for more than two decades Mr. Greer's primary interest has been the business of commodity investment: so much so that the Chicago Mercantile Exchange has referred to him as "the godfather of commodity investing." He has also published articles on the subject in *The Journal of Portfolio Management*, *The Journal of Derivatives*, *The Journal of Alternative Investments*, *Pensions & Investments*, and in the inaugural edition of the *Global Commodities Applied Research Digest*, for which he is also a member of the Editorial Advisory Board. He has consulted on the subject of commodities to the CIA, the Bank of England and the New York Fed, and participated in the CFTC's Agricultural Roundtable in April 2008. Mr. Greer wrote and edited, <u>The Handbook of Inflation Hedging Investments</u>, oriented to the institutional investment community, which was published by McGraw Hill in December 2005. In addition, Mr. Greer wrote the foreword to the book, <u>Intelligent Commodity Investing</u>, which was published by Risk Books in 2007. He also co-authored <u>Intelligent Commodity Indexing</u>, published by McGraw Hill in 2012. Among other interests since retiring from PIMCO, Mr. Greer serves as a scholar-in-residence at the J.P. Morgan Center for Commodities, part of the University of Colorado Denver Business School, and is a member of both the Research Council and the Advisory Council of that organization. He is also a Senior Advisor for CoreCommodity, LLC, a prominent specialty asset manager of commodity mandates. He provides strategic consulting for companies in the physical commodity business, and is a member of PIMCO's Index Oversight Committee. Mr. Greer received a bachelor's degree summa cum laude in mathematics and economics from Southern Methodist University and was in the top 5% of his M.B.A. class at the Stanford Graduate School of Business.

Just a One-Trick Pony? An Analysis of CTA Risk and Return

Jason Foran
Cork University Business School, University College Cork, Ireland

Mark Hutchinson
Cork University Business School, University College Cork, Ireland

David McCarthy
Cork University Business School, University College Cork, Ireland

John O'Brien
Cork University Business School, University College Cork, Ireland

Published in: *Journal of Alternative Investments,* 2017, Vol. 20, No. 2, Fall, pp. 8-26.

In light of the recent popularity of products based on alternative risk premia, the authors examine the ability of these products to capture the returns of the commodity trading advisor (CTA) sector. The empirical analysis indicates that CTAs have heterogeneous return series that cannot be easily replicated through factor investing. Using a novel method, the authors generate the longest bias-free track record for CTAs, running from January 1987 to July 2015 and show consistently positive returns for the industry across the period. Finally, the authors show that CTAs with significant exposure to time series momentum (trend-following) have significantly better returns than those without this exposure.

Introduction

One of the fastest growing segments of the asset management industry is alternative risk premia products. It is claimed that these products offer hedge-fund-like returns with higher liquidity, transparency and relatively low fees. Accordingly, the attractiveness of these products depends upon the ability of risk premia to replicate hedge funds returns. The authors test the above claims using Commodity Trading Advisor (CTA) data. CTAs lend themselves as a useful laboratory in this context as they are one of the longest-established hedge fund categories and there is an extensive academic literature discussing their sources of return, including recent advances in the study of alternative risk premia. The paper addresses two core questions. Do CTAs (or sub-groups of CTAs) follow homogenous easily modelled strategies? And do the returns of CTAs within sub-groups stem from exposure to alternative risk premia?

Why the Paper's Research Questions are Important

The viability of the business model generating hedge-fund-like returns through factor investing is based on two assumptions: i) alternative strategies (hedge funds) have a return profile that is attractive to investors, and ii) it is possible to replicate those returns by factor investing. This paper examines both

---

This digest article was written by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics at Cass Business School, City, University of London (U.K.).

assumptions in the case of CTAs. It finds that while there is strong evidence for long-term positive performance in CTAs, the ability of products to replicate this by investing in risk premia is limited.

Professor Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics at Cass Business School (U.K.) and Editorial Advisory Board Member of the *GCARD*, lecturing in June 2018 at the 16th INFINITI Conference on International Finance in Poznań (Poland). Professor Fuertes is the author of this research digest article.

Data

The analysis is based on the constituents of the BarclayHedge CTA database, which the authors carefully processed to remove well-known biases (see Fung and Hsieh, 2002). The inclusion of live and dead funds eliminates survivorship bias. Backfill bias, the tendency of funds to backfill returns when first reporting, leads to significant over-estimation of performance. The inclusion of a "date added" field post 2002 allows easy removal after this date. Prior to 2002, the authors take a novel approach to eliminating backfill, selecting CTAs based on membership of the BarclayHedge CTA Index. Following the standard approach in the literature, non-U.S. dollar denominated funds, duplicate funds, funds not reporting net of fees, reporting at quarterly intervals, and failing to report assets-under-management (AUM) were also excluded.

Cleaning the database reduced the sample from 5,199 to 3,419 distinct CTAs to generate CTA return series. The number of live funds varies through time but follows an upward trend. Starting from a low of 54 in 1987, the number rises steadily to range between 200 and 250 from 1993 to 2001. It jumps to 390 in 2002, steadily increasing to a peak of 741 in 2011. It has since fallen back slightly.

The clustering methodology requires that funds have at least twelve months of data. This criterion eliminates a further 950 funds, producing a sample of 2,469 CTAs for style analysis. The large drop off in sample size demonstrates the high attrition rate of newly reporting CTAs. The authors estimate that this step puts an upward bias of 3.5 basis points (bps) per month on the performance of clusters.

Methodology

The authors focus on four types of risk premia to analyze performance. They generate three of these from underlying futures data, based on the recent literature: time series momentum (Moskowitz *et al*., 2012), carry (Koijen *et al*., 2018) and value (Asness *et al*., 2012). These risk premia have Sharpe ratios of 0.71, 0.78 and 0.47 respectively. The final risk premium is derived from the well-known option-based factors of Fung and Hsieh (2001).

The authors analyze the performance of CTAs in aggregate and divided into sub-classes. The performance of CTAs (and their sub-classes) is measured as the average return of all relevant live funds in a given month. The authors use both equal-weighted and AUM weighted averages but argue equal-weighted is superior due to unreliable AUM data and very large funds dominating the performance of their clusters. For simplicity, only equal-weighted results are reported here, although both methods produce similar conclusions.

The authors rely on both self-attributed classes of common styles and on classes generated by statistical clustering. The latter approach has been suggested as superior to the self-attributed classes approach in the theoretical literature (Brown and Goetzmann, 1997); the present paper confirms this empirically.

Results

Over the period from January 1987 to July 2015, CTAs generated an average annual return of 7.85% per annum with a Sharpe Ratio of 0.38. The earlier 1987-1993 period is characterized by very high returns and volatility. Post January 1994 the returns were lower at 5.40%; however as this corresponded to lower volatility, the Sharpe ratio remains constant at 0.37. The maximum drawdown was 16% in the early volatile period, but since 1992 it has not reached 10%.

Regression analysis shows all four risk premia contribute to performance although the time series momentum and option-factor premia dominate. The four factors altogether can only explain 34% of the CTA returns. The risk-adjusted return (alpha) is 17 bps per month, although this is only marginally significant. A rolling regression shows this is generated consistently over the sample period.

The analysis identifies eight different clusters reflecting a combination of factor exposure and classification: Diversified Trend (8.27% annual return / 0.42 Sharpe ratio), Long Term Trend (7.48% / 0.37), Short Term Trend (6.40% / 0.34), Fundamental Value (3.13% / 0.05), Fundamental Diversified (3.30% / 0.08), Fundamental Carry (5.21% / 0.32), Discretionary (4.64% / 0.31) and Option Strategies (1.33% / -0.11). Apart from the clusters with a significant exposure to trend following, the correlations between the returns series are low, which represents evidence of heterogeneity in CTA return generating processes. There is a notable correlation between exposure to trend following and performance with the trend-following clusters having the highest return and Sharpe ratio.

The explanatory power of the return factors remains moderate, with the adjusted R^2 ranging from 14% to 44%. Three of the clusters have statistically significant alpha (Diversified Trend, Shorter Term Trend and Discretionary) while the alpha of the option strategy cluster is significantly negative.

While the risk factors provide moderate explanatory power for the clusters, it is superior to that of the self-attributed classes with an adjusted R^2 measure of less than 10% for ten of the sixteen classes. This is consistent with the theory that self-attributed styles are unreliable.

Conclusions

CTAs have consistently generated positive performance across the period from January 1987 to July 2015, returning 7.85% on average with a Sharpe ratio of 0.38. Apart from a high volatility-high return period in the early years, this return has been achieved without significant drawdown. A low cost, high liquidity alternative risk premia product replicating this CTA industry performance would be attractive to investors.

However, the return generating strategies of CTAs are highly heterogeneous. Statistical clustering identifies eight sub-strategies with low cross-correlation and different risk exposures. Alternative risk premia do not explain a large proportion of CTA returns with 56% to 86% of returns unexplained across the eight clusters.

From a practitioner's perspective these results suggest that attempts to capture the returns of CTAs face non-trivial challenges. CTAs are not homogenous, so their returns cannot be easily reproduced. A product which seeks to track aggregate CTA performance is likely to have high tracking error. Subdividing the funds does not help with alternative risk premia representing a moderate proportion of the source of returns for sub-strategies. The findings do not support the claim that new products based on alternative risk premia represent a close substitute to CTA investing. The results suggest that while these new products may deliver on liquidity, transparency and fees, investors expecting to replicate CTA returns may be disappointed.

References

Asness, C., Moskowitz, T. and L. Pedersen, 2013, “Value and Momentum Everywhere,” *Journal of Finance*, Vol. 68, No. 3, June, pp. 929-985.

Brown, S. and W. Goetzmann, 1997, “Mutual Fund Styles,” *Journal of Financial Economics*, Vol. 43, No. 3, March, pp. 373-399.

Fung, W. and D. Hsieh, 2001, “The Risk in Hedge Fund Strategies: Theory and Evidence from Trend Followers,” *Review of Financial Studies*, Vol. 14, No. 2, Summer, pp. 313-341.

Fung, W. and D. Hsieh, 2002, “Hedge Fund Benchmarks: Information Content and Biases,” *Financial Analysts Journal*, Vol. 58, No. 1, January-February, pp. 22-34.

Koijen, R., Moskowitz, T., Pedersen, L. and E. Vrugt, 2018, “Carry,” *Journal of Financial Economics*, Vol. 127, No. 2, February, pp. 197-225.

Moskowitz, T., Ooi, Y. and L. Pedersen, 2012, “Time Series Momentum,” *Journal of Financial Economics*, Vol. 104, No. 2, May, pp. 228-250.

Keywords

Performance measurement, commodity trading advisors, CTA, alternative risk premia.

Child Mortality, Commodity Price Volatility and the Resource Curse

Yousef Makhlouf
College of Business Law and Social Sciences, Nottingham Trent University, U.K.

Neil Kellard
Essex Business School and Essex Finance Centre, University of Essex, U.K.

Dmitri Vinogradov
Adam Smith Business School, University of Glasgow, U.K.

Published in: *Social Science & Medicine*, 2017, Vol. 178, Issue C, pp. 144-156.

The authors investigate empirically the impact of commodity price movements on child mortality using panel data for 69 low and lower-middle income countries from 1970 to 2010. They find that commodity terms-of-trade volatility increases child mortality in highly commodity-dependent importers suggesting a "scarce" resource curse. They also find that the presence of sound institutions (proxied by democracy) mitigates the harmful impact of commodity price volatility. They conclude that an effective approach to improving child wellbeing in low to lower-middle income countries will combine hedging, import diversification and improvement of institutional quality.

Introduction

The child mortality rate is shockingly high in many low and lower-middle income countries. For example, in 2015 there were 6 million deaths of under-fives worldwide, of which 3 million occurred in Sub-Saharan Africa (86 deaths per 1000 live births) and 1.8 million in Southern Asia (50 deaths per 1000 live births). Such regions typically contain countries that are particularly dependent either on commodity exports or imports or both. *Prima facie* this suggests a potential linkage between commodity prices and child mortality. There are several reasons why such a relationship may hold; booms in food prices are theorized to lead to malnutrition (Christian, 2010), and more broadly, commodity prices affect macroeconomic conditions (Céspedes and Velasco, 2014), which in turn determine infant mortality rates (Baird *et al*., 2011). This potential linkage deserves to be thoroughly explored in the literature.

The authors study the impact of the growth and volatility of commodity prices on child mortality and, in doing so, they extend previous work examining (i) the relationship between economic growth and natural resource endowments (e.g., Sachs and Warner, 2001), which is known as the "resource curse," and (ii) the linkages between such endowments and serious health conditions (de Soysa and Gizelis, 2013).

This digest article was written by Ana-Maria Fuertes, Ph.D., Professor in Finance and Econometrics at Cass Business School, City, University of London (U.K.).

Relevance of the Research Question

Only a few studies test the potential linkage between commodity prices and child mortality. Miller and Urdinola (2010), for example, examine the case of Colombia using three episodes of sharp coffee price swings in 1975, 1985 and 1989-90. Lee *et al*. (2016) test the impact of food price inflation on infant mortality for a panel of developing countries over the period 2001-2011. However, it is still unclear whether it is the level (or the growth) and/or the volatility of commodity prices that affects child mortality. Specifically, the present paper provides a new theoretical framework that includes both the level and the volatility. Moreover, the authors explore the role of the quality of institutions to mitigate the potential harmful effects of the growth and/or volatility of commodity prices on child mortality.

Theoretical Framework

The authors adopt a theoretical framework that leads to four hypotheses: (1) food prices are not the only commodity price that affects child mortality rates in commodity-dependent countries; (2) level changes (or growth) in commodity prices have different directional effects on child mortality for net exporters and importers; (3) commodity price volatility adversely affects the rate of child mortality; and (4) better institutions limit the latter effect.

Data and Methodology

Using data for 69 low and middle-low income countries over the period from 1970 to 2010, the authors apply panel ordinary least squares (POLS) estimation. In particular, they use data on a country-specific "commodity terms-of-trade" index (CTOT hereafter), which incorporates a number of commodities and reflects an individual country's overall position in the commodity market (or national commodity trade structure.) Accordingly, movements in global commodity prices affect the CTOT differently across countries (Spatafora and Tytell, 2009). The authors additionally decompose the CTOT into energy and non-energy CTOT to examine the first hypothesis. They also split the sample into net commodity exporters (25 countries) and net commodity importers (44 countries) to test the second and third hypotheses. They compare these groups with two smaller sub-samples consisting of the most commodity-dependent countries to assess the impact of the degree of commodity dependence. Finally, they use a democracy index, as well as a distribution-of-resources index, as proxies of the quality of a country's institutions, to examine the fourth hypothesis.

Results

The authors find that the main driver through which commodity prices can affect child mortality is their volatility, not the growth rate. As an explanation for the latter, they show that the CTOT of developing countries exhibits either no or weak trend. They further demonstrate that the volatility effect is at play mostly in those countries that depend heavily on commodity imports; these countries tend to suffer more from higher commodity price volatility than heavily commodity-dependent exporters. This not only illustrates the adverse impact of high commodity dependence on child survival but also reveals a new "scarce" resource curse. In other words, while the well-known resource curse applies to countries that have an abundance of a natural resource, the "scarce" resource curse means that commodity price volatility is particularly harmful for child mortality in countries that need to import essential resources. To shed light on the channels of this commodity price volatility effect, the authors decompose the CTOT into energy and non-energy (mainly food) CTOT. The energy volatility effect on child mortality is significant for heavily commodity-dependent importers whereas the non-energy volatility has no effect. This implies that movements in global food commodity prices are subordinate to those of energy when considering the impact on child mortality. The results suggest also that sound institutions, as proxied by democratic regimes, can shield importer countries from some of the detrimental effects of volatility, whereas autocratic regimes cannot.

Conclusions

The authors discuss theoretically the political and economic aspects that may link commodity price movements and child mortality in developing countries and examine various testable predictions. Their empirical analysis suggests that it is the volatility and not the growth rate of commodity prices that adversely affects child mortality in developing countries. This harmful linkage between commodity price volatility and child mortality is present primarily in heavily commodity-dependent importers, which reveals a "scarce" resource curse, and more so in countries with poor-quality (autocratic) institutions. The analysis prescribes improving institutional quality, the use of financial hedging, and reducing commodity dependence through import substitution strategies and/or diversification of the commodity basket in developing countries.

References

Baird, S., Friedman, J. and N. Schady, 2011, "Aggregate Income Shocks and Infant Mortality in the Developing World," *Review of Economics and Statistics*, Vol. 93, No. 3, August, pp. 847-856.

Céspedes, L.F. and A. Velasco, 2014, "Was This Time Different?: Fiscal Policy in Commodity Republics," *Journal of Development Economics*, Vol. 106, January, pp. 92-106.

Christian, P., 2010, "Impact of the Economic Crisis and Increase in Food Prices on Child Mortality: Exploring Nutritional Pathways," *The Journal of Nutrition*, Vol. 140, No. 1, January, pp. 177S-181S.

de Soysa, I. and T. Gizelis, 2013, "The Natural Resource Curse and the Spread of HIV/AIDS, 1990-2008," *Social Science & Medicine*, Vol. 77, Issue C, pp. 90-96.

Lee, H., Lee, S., Lim, J. and C. Park, 2016, "Effects of Food Price Inflation on Infant and Child Mortality in Developing Countries," *The European Journal of Health Economics*, Vol. 17, No. 5, June, pp. 535-551.

Miller, G. and B. Urdinola, 2010, "Cyclicality, Mortality, and the Value of Time: The Case of Coffee Price Fluctuations and Child Survival in Colombia," *Journal of Political Economy*, Vol. 118, No. 1, February, pp. 113-155.

Sachs, J. and A. Warner, 2001, "The Curse of Natural Resources," *European Economic Review*, Vol. 45, Nos. 4-6, February, pp. 827-838.

Spatafora, N. and I. Tytell, 2009, "Commodity Terms of Trade: The History of Booms and Busts," IMF Working Paper, pp. 1-34.

Keywords

Low and lower-middle income countries, commodity prices, terms-of-trade, institutions, resource curse, child mortality.

An Additional Aspect of Whether Futures Contracts Succeed: The Nature of Governmental Intervention

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

Ms. Hilary Till, the Contributing Editor of the *Global Commodities Applied Research Digest (GCARD)*, presenting at the J.P. Morgan Center for Commodities' Advisory Council meeting on March 8, 2018.

Introduction

In the Spring 2016 issue of the *GCARD*, we summarized the three conditions that have historically determined whether a futures contract succeeds or not: (1) there must be a commercial need for hedging; (2) a pool of speculators must be attracted to a market; and (3) public policy should not be too adverse to futures trading.

Commercial Need for Hedging

We elaborated on the first condition in the Summer 2018 issue of the *GCARD*. In that issue, we discussed examples of successful futures contracts that responded to new large-scale commercial risks over the past 170 years, noting the new commercial circumstances that ushered in the intense need for hedging instruments.

Pool of Speculators

The second condition for a futures contract's success concerns the need to attract a sufficient amount of speculative interest. This feature was discussed by Professor Robert Webb of the University of Virginia during his lecture at the J.P. Morgan Center for Commodities' August 2018 international commodities symposium.

Dr. Robert Webb, Ph.D., Martin J. Patsel Jr. Research Professor, University of Virginia; and Editor, *Journal of Futures Markets*, provided the keynote address during the first day of the JPMCC's 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 through August 15, 2018. Dr. Webb's presentation answered the question, "What Drives Success in Derivatives Markets?" Dr. Webb is also a member of the JPMCC's Research Council.

Dr. Webb explained that amongst the factors responsible for driving the success of a futures contract is "having speculators willing to risk their own capital ... Large institutions sometimes become risk averse just when the market needs them most."

Absence of Onerous Governmental Intervention

Our current digest article, in turn, covers the third necessary condition for a futures contract's success: a contract must not be subject to particularly onerous regulations or laws.

The Regulation of Futures Contracts

The history of futures regulation is one of infrequent but often disruptive interventions following natural disasters or events that undermine public confidence in exchanges. It turns out that the history of futures regulations reveals four features: (a) a contract must have a convincing economic rationale; (b) it is helpful if contracts are viewed as being in the national interest; (c) competition requires regulatory parity among exchanges; and (d) markets can survive even draconian interventions so long as they are short-term.

If the Economic Rationale Is Not Convincing, a Contract is at Risk of Being Banned or Heavily Curtailed

<u>Berlin Futures Contracts (Late 1890s)</u>

According to Jacks (2007), "In the wake of a disastrous harvest in 1891 at home and [in] Russia, grain consumers in the German Reich suffered an increase in both the level and volatility of prices. Public agitation against speculative ventures on the Bourse was met with open arms ... in the Reichstag … [Accordingly,] [f]rom January 1, 1897 … dealing in grain futures was banned outright …"

"It became apparent that … [the law] had seemingly failed to accomplish its most touted benefit, the stabilization of commodity prices," noted Jacks. The law "was rescinded early in 1900. In April of that year, the Berlin futures market in grain was reopened."

<u>U.S. Onion Futures Contracts (1958)</u>

Jacks (2007) also discussed the banning of onion futures trading in the United States. "[T]he United States Congress in the fall of 1958 passed the Onion Futures Act. The intent of the Senate Committee on Agriculture and Forestry was clear: given 'that speculative activity in the futures markets causes such severe and unwarranted fluctuations in the price of cash onions … [a] complete prohibition of onion futures trading in order to assure the orderly flow of onions in interstate commerce' was enacted. … [T]his law is significant in that it mark[ed] the first … time in the history of the United States that futures trading in any commodity was banned."

The reason for the "bill's passage could be explained by a basic lack of knowledge on the workings of the fresh onion market. The ability to store crops from year to year is [effectively] nonexistent," explained Jacks. Therefore, it is natural that there are "sometimes large adjustment[s] in price as the harvest approaches … The finding that there was … [significant] price volatility … should have come as no surprise."

Working (1963) concluded: "futures trading in onions was prohibited because too few members of Congress believed that the onion futures market was, on balance, economically useful."

History of U.S. Futures Market Regulation

Working also noted how close the U.S. came to duplicating the 1890s German experience with a futures trading ban. In the U.S., "a bill that would have imposed destructive taxation on all existing futures trading in farm products narrowly escaped passage by both houses of Congress in 1893 ... A similar bill considered by the … [next] Congress gained passage only in the House …"

Jacks (2007), in turn, documented at least 330 bills introduced to the U.S. Congress between 1884 and 1953 to "limit, obstruct, or prohibit futures trading." Tables 1 through 6 below (and in successive pages) show how frequent government interventions have been in the U.S. futures markets since the 1920s. After reviewing this history, it is clear that it will always be an ongoing effort to demonstrate the economic usefulness of futures trading.

Table 1
Governmental Interventions in the U.S. Futures Markets, 1921–1927

Date	Regulation	Action
September 1921	Futures Trading Act	The Act provides for the regulation of futures trading in grains such as corn, wheat, oats, and rye. The Act empowers the U.S. Secretary of Agriculture to designate exchanges that meet certain requirements as "contract markets" in grain futures. The aim was to prevent market manipulation by the exchanges' members, firms, and employees. The Act also imposed a prohibitive USc20 per bushel tax on all options trades and on grain futures trades that were not executed on a designated contract market as specified by the Federal Government.
September 1922	Grain Futures Act	The 1921 Futures Trading Act is declared unconstitutional. Instead of taxing futures and options trading, the 1922 Act bans off-contract-market futures trading.
June 1923		The Grain Futures Exchange implements a large-trader reporting system. It requires each clearing member to report on a daily basis the market positions of each trader exceeding a specified size.
February 1927		The Secretary of Agriculture suspends until November 1927 large-trader reporting requirements. This follows complaints that the requirements were preventing large bullish speculators from entering the market, thus allegedly depressing grain prices. Following the suspension, the Grain Futures Administration determines that large-trader reporting requirements did not discourage bullish speculators.

Source: Lewis (2009).

Table 2
Governmental Interventions in the U.S. Futures Markets, 1936–1958

Date	Regulation	Action
June 1936	Commodity Exchange Act	Following the collapse in grain and cotton prices during the 1930s, the Commodity Exchange Commission (CEC) was established. The 1936 Act extends and strengthens the government's regulatory powers to a longer list of commodities. The act provided for the adoption of position and trading limits to restrict the number of futures contracts that could be held by large individual speculators. It also prohibits the trading of options on commodities traded on futures exchanges.
December 1947	Amendment to the 1936 Commodity Exchange Act	The Commodity Exchange Authority replaces the CEC. Following a rise in commodity prices after WWII, the Act allows the publication of the names and addresses and market positions of large traders. In its first declaration, the Secretary of Agriculture publishes the names of 35,000 traders. President Truman orders the CEA to require futures exchanges to raise margin requirements to 33% on all speculative positions.
August 1958	Onion Futures Act	Trading in the Golden Globe onion futures contract on the Chicago Mercantile Exchange is banned. This followed [perceived] excessive moves in the onion price during 1955.

Source: Lewis (2009).

Table 3
Governmental Intervention in the U.S. Futures Markets, 1974

Date	Regulation	Action
October 1974	Commodity Futures Trading Commission Act	The Commodity Futures Trading Commission (CFTC) is established. It extends the jurisdiction of the CFTC from agricultural commodities to futures trading in all commodities, which becomes effective in April 1975.

Source: Lewis (2009).

"U.S. and international commodity markets experienced a period of rapid increases from 1972–1975, setting new all-time highs across a broad range of markets," according to Cooper and Lawrence (1975). Those price increases were blamed on speculative behavior associated with the "tremendous expansion of trading in futures in a wide range of commodities," noted the two authors.

Not surprisingly, "public pressure to curb speculation resulted in a number of regulatory proposals," wrote Sanders *et al.* (2008). "In hindsight, economists generally consider this a period marked by rapid structural shifts such as oil embargoes, Russian grain imports, and the collapse of the Bretton Woods fixed exchange-rate system," according to Cooper and Lawrence (1975). The recognition of the fundamental economic factors explaining the dramatic price rises in commodities helped ensure draconian regulation on futures trading did not ensue.

Table 4
Governmental Interventions in the U.S. Futures Markets, 1977–1979

Date	Regulation	Action
August 1977		The CFTC requests the U.S. District Court in Chicago to instruct the Hunt family of Dallas to liquidate positions that exceed [the] three million bushel speculative position limit for soybean futures on the CBOT.
March 1979		The CFTC votes to prohibit trading in the CBOT March wheat futures contract. This is the first time the Commission has ordered a market to close in the interest of preventing price manipulation.

Source: Lewis (2009).

One significant regulatory change in the 1980s was the removal of the 50-year ban of options on commodities.

Table 5
Governmental Interventions in the U.S. Futures Markets, 1980–2009

Date	Regulation	Action
March 1980		After careful consideration, the CFTC votes not to use its emergency powers to order suspension of trading in silver futures as prices plummet.
October 1981	Regulation 1.61	The CFTC requires exchanges to establish speculative position limits in all futures contracts.
January 1991		The CFTC reports to Congress that it finds no evidence that the sharp rise in energy prices has been caused by manipulation or excessive speculation.
August 2004		After a seven-month investigation, the CFTC concludes that there is no evidence that any entity or individual attempts to distort natural gas prices in late 2003.
Summer 2009		The CFTC holds three public hearings to discuss speculative position limits and exemptions in energy markets.

Source: Lewis (2009).

Contracts Are Viewed as Being in the National Interest

From a public policy standpoint, it is clearly helpful if futures markets are seen as a benefit to the nation as a whole, as the following examples illustrate.

Foreign Currency Futures

Milton Friedman invoked the national interest argument in a 1971 paper supporting the development of a foreign-currency futures market. "As Britain demonstrated in the 19th Century, financial services of all kinds can be a highly profitable export commodity. … It is clearly in our national interest that a satisfactory futures market [in currencies] should develop, wherever it may do so since that would promote U.S. foreign trade and investment. But it is even more in our national interest that it develop here instead of abroad," wrote Friedman (1971).

The development of a currency futures market in the U.S. "will encourage the growth of other financial activities in this country, providing … additional income from the export of [financial] services," concluded Friedman.

Financial Futures

Silber (1985) discussed the advantages for the economy as a whole resulting from the creation of financial futures contracts: the "main contribution" of financial futures "is a reduction in transaction costs [as compared to the relevant cash markets] and an improvement in market liquidity … the ultimate benefit being a reduction in the cost of capital to business firms [, which, in turn, leads to] greater capital formation for the economy as a whole."

Crude Oil Futures

One crucial economic function of commodity futures markets is to enable the hedging of prohibitively expensive inventories with the assumed result that more inventories are privately held than otherwise would be the case. If commodity futures markets do perform that function, then one would expect their existence would lessen price volatility (Till, 2014). More oil inventories held than otherwise would be the case could lessen the possibility of oil price spikes, as argued in Verleger (2010).

Competition Promotes Regulatory Parity

If a futures exchange does not have regulatory parity with another similar exchange, it could lose market share.

ICE vs. NYMEX

According to Dowd (2007), as of 2006, there was "a significant regulatory imbalance between the two regulating authorities, the … [U.K. financial regulator] and CFTC. By holding positions in the ICE [WTI] Futures contract, traders d[id] not have CFTC-mandated position limits to worry about, nor … [were] they required to comply with CFTC weekly position reporting requirements. … One former director [of oversight at CFTC] said … [in 2006] that the Nymex '[wa]s at risk of losing WTI', and [then] CFTC Commissioner Walt Lukken … stated that 'agencies must remain flexible and tailored in their approach or fear losing these markets to other jurisdictions,'" wrote Dowd.

The regulatory situation was rebalanced in June 2008: "The U.S. commodity futures regulator … [reported] ICE Futures Europe … agreed to make permanent position and accountability limits for … its U.S.-traded crude contracts, subjecting itself to the same regulatory oversight as its New York based counterpart. Following intense scrutiny … by Congress … the U.S. Commodity Futures Trading Commission also said it would require daily large trader reports, and similar position and accountability limits from other foreign exchanges" for contracts that are based on U.S. commodities, according to Talley (2008).

Markets Can Survive Even Draconian Interventions So Long as They Are Short-Term

If regulatory interventions are draconian but only short-term, futures markets can survive. The suspension of grain futures trading in January 1980 is summarized in Table 6. Such an action, while "well-intentioned [was] ... a direct restraint on [a] futures market['s] free operation and [was] ... intended to override the ability of buyers and sellers in the market to negotiate prices freely," wrote Johnson and Hazen (2004).

Table 6
Government Intervention in the U.S. Futures Markets, 1980

Date	Regulation	Action
January 1980		In an emergency action, the CFTC orders the *suspension of futures trading* for two days for wheat, corn, oats, soybean meal, and soybean oil on four exchanges after President Carter announces an embargo on the sale of certain agricultural goods to the Soviet Union that includes substantial amounts of grain. [Italics added.]

Source: CFTC.

"Therefore, to the extent that the markets fall short of the economic theory of pure competition, contributing factors ... must also include acts of government and regulatory intervention," concluded Johnson and Hazen (2004).

Fortunately, the trading suspension only had a minor effect on grain futures trading and did not damage these markets. Lothian (2009) explained why the grain markets were not materially disrupted by the temporary suspension of U.S. grain futures trading: "[W]hen President Carter's administration shut down trading for several days on the U.S. grain futures exchanges, traders … [responded] by trading contracts on the Winnipeg Commodity Exchange [in Canada.] Rather than waiting to offset their long positions at substantially lower prices when the U.S. exchanges reopened and beg[i]n trading after a limit down move in prices, some traders [immediately] shorted Winnipeg grain futures contracts to hedge their positions. In an example of the law of unintended consequences, price discovery moved from Chicago to Winnipeg for soybeans, corn and wheat through the surrogates of rape seed, feed wheat and other contracts."

Having an alternative exchange in Canada with which to manage risk meant the action taken by the Carter administration did not have a draconian impact on U.S. grain futures traders.

Conclusion

Lawmakers have tried repeatedly to "limit, obstruct, or prohibit futures trading" (Jacks, 2007) based on the public's misunderstanding of how futures contracts are self-regulating and their essential role in helping businesses manage risks. Pressure for increased regulation often follows economic disruptions such as the rapid inflation that followed the collapse of the Bretton Woods system in 1971 and the oil embargo of 1973-1974 when speculators were blamed for price spikes.

Markets discipline government regulators as well as speculators and commercial hedgers. Exchanges compete furiously with one another, requiring national regulators to establish regulatory parity with other countries or risk losing the economic benefits of being the home of successful exchanges. The existence of competing exchanges and futures contracts means even draconian regulation such as banning trading in a particular commodity cannot prevent markets from finding alternative ways to manage risk, a fact illustrated by the market response to the Carter administration's suspension of U.S. grain futures trading for two days in 1980.

Futures markets, like all social institutions that have successfully evolved over time, require "umpires," so this article is not advocating the absence of government oversight, but the history of U.S. futures markets has to be seen for what it is: one of continuous confrontation with activist public policy. Accordingly, the industry must educate the public and policymakers about the important role it plays in a global economy and the benefits it produces for the public in order to avoid needless and counterproductive regulation (and laws), which can jeopardize the success of economically useful futures contracts.

Endnotes

This digest article is, in the main, excerpted from a seminar that was prepared by the author for staff at the Shanghai Futures Exchange. In addition, a comprehensive version of this article benefitted from insightful comments and inferences from Joseph Bast.

References

Cooper, R. and R. Lawrence, 1975, "The 1972-1975 Commodity Boom," *Brookings Papers on Economic Activity*, Vol. 6, No. 3, pp. 671–724.

Friedman, M., 1971, "The Need for Futures Markets in Currencies," Commissioned Paper for the Chicago Mercantile Exchange, December 20.

Dowd, G., 2007, "The Move to Electronic Trading: What to Expect in the Natural-Resources Markets," in H. Till and J. Eagleeye (eds) Intelligent Commodity Investing, London: Risk Books, pp. 501–515.

Jacks, D., 2007, "Populists Versus Theorists: Futures Markets and the Volatility of Prices," *Explorations in Economic History*, Elsevier, Vol. 44, No. 2, April, pp. 342–362.

Johnson, P. and T. Hazen, 2004, Derivatives Regulation, Frederick, MD: Aspen Publishers.

Lewis, M., 2009, "U.S. Regulators and Speculators: A Long History of Confrontation," Deutsche Bank Global Markets Research, August 17.

Lothian, J., 2009, Testimony Before the U.S. Commodity Futures Trading Commission Regarding "Open Hearings to Discuss Energy Position Limits and Hedge Exemptions," Washington D.C., July 29. Accessed via website: http://www.cftc.gov/ucm/groups/public/@newsroom/documents/file/hearing072909_lothian.pdf on October 27, 2018.

Sanders, D., Irwin, S. and R. Merrin, 2008, "The Adequacy of Speculation in Agricultural Futures Markets: Too Much of a Good Thing?" Marketing and Outlook Research Report 2008-02, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, June.

Silber, W., 1985, "The Economic Role of Financial Futures," in A. Peck (ed) Futures Markets: Their Economic Role, Washington D.C.: American Enterprise Institute for Public Policy Research, pp. 83-114.

Talley, I., 2008, "Limits Put on Some Oil Contracts on ICE Amid Outcry Over Prices," *Wall Street Journal*, June 17.

Till, H., 2014, "Hedging and Speculation: A Discussion on the Economic Role of Commodity Futures Markets (Including the Oil Markets," in A. Dorsman, T. Gök, and M. Karan (eds) Perspectives on Energy Risk, Heidelberg: Springer, pp. 145-164.

Till, H., 2016, "Brief Case Studies on Futures Contract Successes and Failures," *Global Commodities Applied Research Digest*, Contributing Editor's Collection, Vol. 1, No. 1, Spring, pp. 62-66.

Till, H., 2018, "From Grain to Natural Gas: The Historical Circumstances that Led to the Need for Futures Contracts," *Global Commodities Applied Research Digest*, Contributing Editor's Collection, Vol. 3, No. 1, Summer, pp. 90-94.

Verleger, P., 2010, "First Do No Harm," Speech to the Futures Industry Association, March 11.

Webb, R., 2018, "What Drives Success in Derivatives Markets?", Keynote Presentation, 2nd International Commodities Symposium, J.P. Morgan Center for Commodities, University of Colorado Denver Business School, August 14. Accessed via website: http://www.jpmcc-gcard.com/wp-content/uploads/2018/10/Webb-What-Drives-Success-in-Derivatives-Markets-August-14-2018.pdf on November 11, 2018.

Working, H., 1963, "Futures Markets Under Renewed Attack," *Food Research Institute Studies*, Vol. 4, No. 1, pp. 1–24.

Author Biography

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

Jointly with Joseph Eagleeye, Hilary Till is also a principal of Premia Research LLC, which designs investment indices that are calculated by S&P Dow Jones Indices. Prior to Premia, Ms. Till was the Chief of Derivatives Strategies at Putnam Investments where she oversaw the strategy development and execution of about $90 billion annually in exchange-traded and over-the-counter derivatives; and before Putnam, Ms. Till was a Quantitative Analyst at the Harvard Management Company, the university's endowment firm. Ms. Till's additional academic affiliations include her membership in the North American Advisory Board of the London School of Economics and her position as a Research Associate at the EDHEC-Risk Institute (France.)

In Chicago, Ms. Till is a member of both the Federal Reserve Bank of Chicago's Working Group on Financial Markets and the Advisory Board of DePaul University's Arditti Center for Risk Management. She also has provided seminars (in Chicago) to staff from the Shanghai Futures Exchange, China Financial Futures Exchange, Zhengzhou Commodity Exchange, and the Dalian Commodity Exchange. In addition, Ms. Till is a board member of the International Association for Quantitative Finance (New York).

Ms. Till has presented her analyses of commodity futures markets to the following institutions: the U.S. Commodity Futures Trading Commission, the International Energy Agency, and to the (then) U.K. Financial Services Authority. Most recently, she was a panel member at both the U.S. Energy Information Administration's workshop on the "evolution of the petroleum market and [its] price dynamics" and the Bank of Canada's joint roundtable with the International Energy Forum on "commodity cycles and their implications." She is also the co-editor of the bestselling Risk Book (London), Intelligent Commodity Investing.

Ms. Till has a B.A. with General Honors in Statistics from the University of Chicago and an M.Sc. degree in Statistics from the London School of Economics (LSE). She studied at the LSE under a private fellowship administered by the Fulbright Commission.

The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy

Adam Sieminski, CFA
President, King Abdullah Petroleum Studies and Research Center (KAPSARC), Saudi Arabia

Mr. Adam Sieminski, CFA, President, King Abdullah Petroleum Studies and Research Center (KAPSARC), Saudi Arabia.

Rising international oil prices and increased geopolitical uncertainty have put OPEC's spare production capacity back into the spotlight. KAPSARC's recent peer-reviewed collaborative study in the *Energy Journal* by authors Axel Pierru, James L. Smith, and Tamim Zamrik finds that OPEC's spare capacity reduces oil price volatility and generates between $170 and $200 billion of annual economic benefits for the global economy.

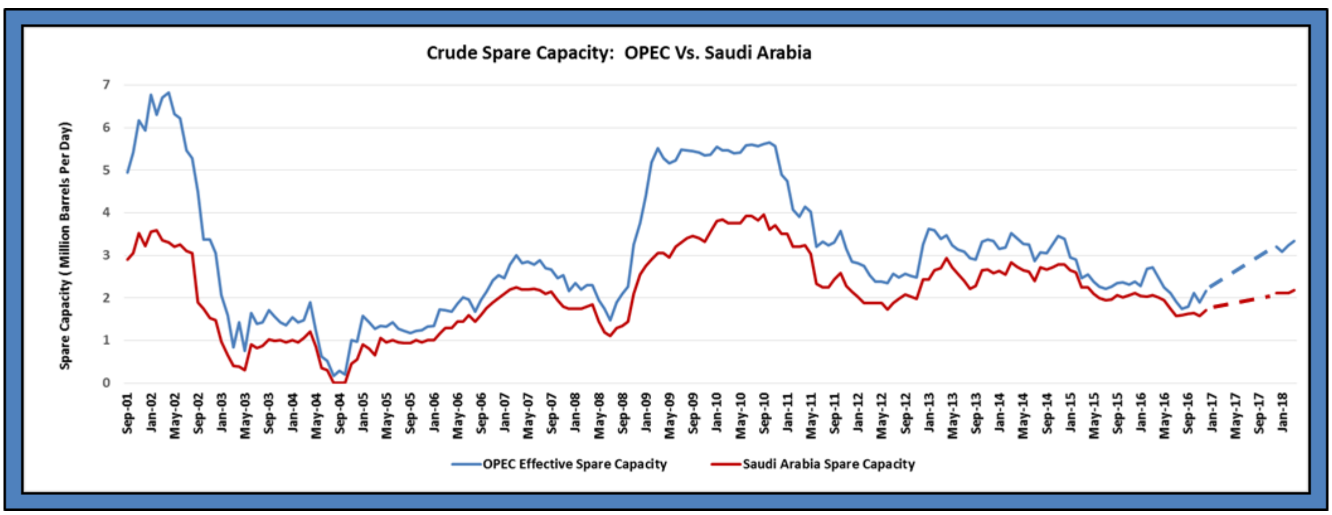
Investments in spare capacity provide value to the economy because deploying the production held in response to disruptions saves costs that result from price volatility. This value can be calculated by subtracting the gross domestic profit (GDP) losses that the world would expect to suffer even after deploying the spare capacity buffer from the expected losses without the buffer. The expected losses depend on the buffer size, the magnitude and persistence of the shocks, and on the global GDP losses incurred when there are production shortfalls.

For many years analysts have judged oil market stability by considering the level of excess production capacity maintained almost exclusively by OPEC. The production and delivery of oil to the market is subject to frequent disruptions, whether from conflicts, natural disasters, labor strikes, port closures, or political sanctions. In addition, demand can be affected by other factors such as the general state of the global economy. The rigidity of demand and supply magnifies the impact of any disruption, and restoring equilibrium to the market often requires sharp price movements, especially in the short term.

These sharp movements and the financial risk premium associated with volatility impose costs on the global economy if they are not dampened through mechanisms including the release of strategic stocks held by major oil importers, redirection of oil tankers to fill geographical imbalances, or increases in production from OPEC spare capacity. Historical examples where OPEC has used its spare capacity to stabilize the market include increasing members' production to meet the unexpected buildup of global oil demand from 2003-2004, and to compensate for the collapse of Libya's oil production following the uprising of 2011.

Figure 1 shows the change in monthly "effective" spare capacity reported by the International Energy Agency (IEA) since 2001. OPEC's spare capacity amounted to 3.24 million barrels per day in June 2018, with world oil demand forecast to reach 100 million barrels per day by the end of the year. Saudi Arabia has held, on average, 70 percent of OPEC's total spare capacity since 2001.

Figure 1
OPEC's Effective Spare Capacity



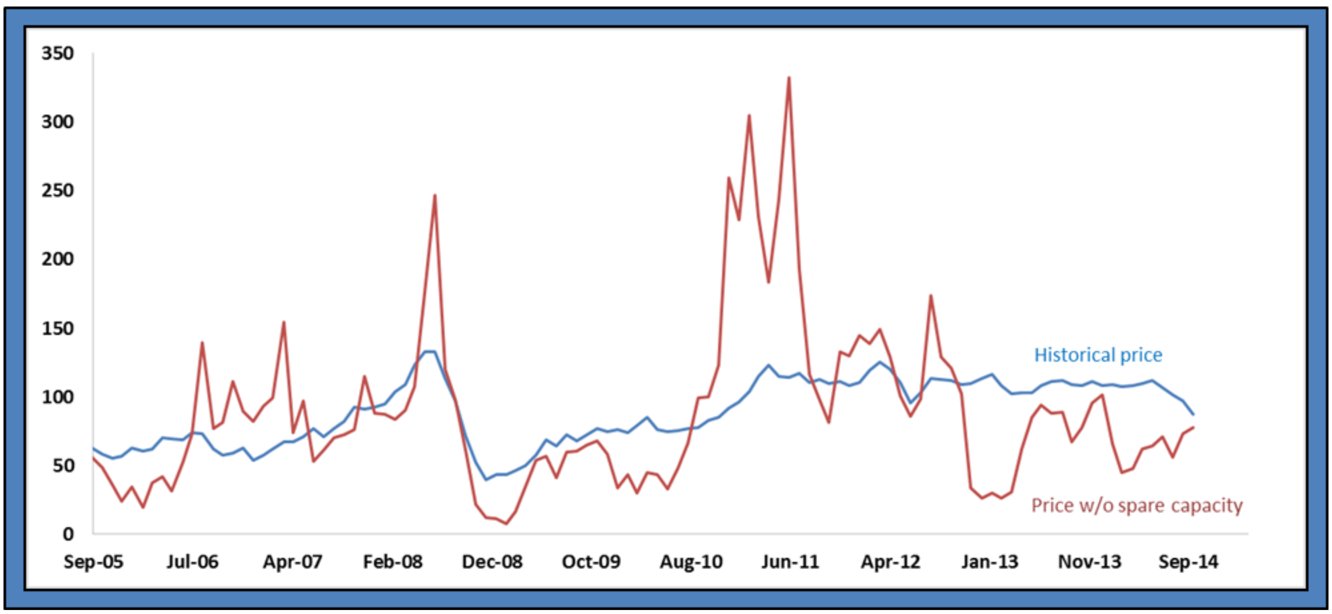
Note: IEA did not report data from January to November 2017.

Source: IEA Monthly Oil Market Reports.

The study uses monthly data to build and estimate a model to analyze a "counterfactual" scenario – comparing what would have been the outcome if OPEC had not deployed spare capacity to the actual outcome observed in global oil markets. The model describes how OPEC maintains a buffer of spare capacity that it uses to offset perceived shocks to global oil demand and supply. The analysis of OPEC's behavior recognizes that the economic, industrial or geopolitical information necessary to accurately judge the size of such shocks is never fully available, which limits OPEC's ability to stabilize the price of oil. In addition, the model accounts for OPEC's logistical constraints and compliance levels.

The counterfactual scenario is based on estimates of the monthly oil prices that would have prevailed from 2005 to 2014 had OPEC not used its spare capacity to offset shocks. These hypothetical prices are compared to the prices historically observed. There is no consensus on how price responsive global demand is. The study examines the effects of a range of monthly price elasticity estimates. Figure 2, based on a monthly price elasticity of -1 percent, is representative of the type of impact that OPEC's spare capacity policy has had. The analysis indicates that OPEC had a substantial stabilizing influence, perhaps reducing oil price volatility by as much as half. The same conclusion holds when the analysis only considers Saudi Arabia, or the four Gulf Cooperation Council members of OPEC collectively. Indeed, the analysis finds that Saudi Arabia has played a greater role in offsetting shocks than all other OPEC members combined.

Figure 2
OPEC's Spare Capacity Reduces Oil Price Volatility



Note: Price with no spare capacity policy based on -1% monthly price elasticity for global demand.

Source: Estimates from authors of the article, "OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity," *Energy Journal*, Vol. 39, No. 2, April 2018 by Axel Pierru, James L. Smith and Tamim Zamrik.

The study also examines the magnitude of spare capacity. This is especially relevant given that the absolute level of spare capacity is now less than it was two decades ago, despite oil demand having grown by 25 percent. To estimate the desired size of the buffer, the study attempts to consider all possible shocks and their respective likelihoods, and then compare the value of spare capacity to the cost of building it. The "right size" is when the cost of adding a marginal barrel per day of capacity is equal to the GDP loss that would arise without that additional barrel of capacity. The analysis confirms that OPEC's buffer, estimated at 2.64 million barrels per day (1.94 million barrels per day for Saudi Arabia), has been in line with global macroeconomic needs.

Spare capacity is only one piece of a much larger picture in terms of neutralizing the negative impact of oil shocks. By maintaining costly inventories, individual consumers, producers, government agencies, and multilateral organizations also shoulder part of the burden of dealing with oil price shocks. This has not been entirely altruistic because spare capacity has a value to the holders: production from the buffer is typically put on the market when prices are high.

The recent emergence of shale oil as the world's marginal producer, with a development lead time measured in months, has made non-OPEC supply much more reactive to price. By contributing to market stability, shale oil is capturing a share of the historical value of spare capacity for the world economy and reducing the incentive for OPEC members to invest in maintaining the cushion. However, shale oil is also subject to potential logistical constraints, such as those currently limiting its expansion in West Texas. Furthermore, it does not suffice to rapidly offset unanticipated shocks of large magnitude. As such, it does not provide sufficient protection for the world economy and OPEC spare capacity still provides value in stabilizing oil markets.

Endnotes

This commentary is based on a KAPSARC research project initiated in late 2016, resulting in the April 2018 publication of the paper, "OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity," in the *Energy Journal*, Vol. 39, No. 2, 2018.

This article is reproduced by kind permission of KAPSARC from the July 17, 2018 commentary by Adam Sieminski, CFA, President, KAPSARC.

Author Biography

ADAM SIEMINSKI, CFA
President, King Abdullah Petroleum Studies and Research Center (KAPSARC), Saudi Arabia

Mr. Adam Sieminski, CFA was appointed as the president of King Abdullah Petroleum Studies and Research Center (KAPSARC) in April 2018. Before his appointment, Mr. Sieminski held the James R. Schlesinger Chair for Energy and Geopolitics at the Center for Strategic and International Studies (CSIS). Prior to that, he was a non-resident senior adviser to the CSIS Energy and National Security Program. He also served as the administrator of the U.S. Energy Information Administration (EIA) from 2012 to 2017 and was the senior director for energy and environment on the staff of the U.S. National Security Council. Earlier in his career, Mr. Sieminski was Deutsche Bank's chief energy economist and the senior energy analyst for NatWest Securities. In 2006, he was appointed to the National Petroleum Council (NPC), where he helped co-author NPC's global oil and gas study.

Mr. Sieminski's membership of leading policy and research organizations includes the roles of senior fellow and former president of the U.S. Association for Energy Economics, and president of the U.S. National Association of Petroleum Investment Analysts. He formerly served as an advisory board member of the Global Energy and Environment Initiative at Johns Hopkins University's School of Advanced International Studies, as chairman of the Supply-Demand Committee of the Independent Petroleum Association of America, and as a member of the Strategic Energy Task Force of the Council on Foreign Relations. He holds the Chartered Financial Analyst (CFA) designation and has received both an undergraduate degree in civil engineering and a master's degree in public administration from Cornell University.

What are the Factors that are Impacting Global Oil Prices?

Robert McNally
Founder and President, Rapidan Energy Group

Market and Price Developments

Over the past year, the global oil market transitioned from a glut to a more "normal" state regarding observed commercial inventories in the Organization for Economic Co-operation and Development (OECD) countries. Excessive inventories accumulated after 2014 as producers ramped up production and U.S. shale oil proved resilient to lower prices. The daily price of West Texas Intermediate (WTI) crude oil fell from a high of $107 per barrel in the summer of 2014 to a low of $26 in February of 2016. Since the beginning of the modern oil market in 1859, crude oil price busts have terrified the oil industry and have often induced producers to restrain production collectively. The price plunge to $26 was no different: over the course of 2016, Saudi Arabia and Russia assembled a new coalition of producers with the aim of eliminating oversupply to prevent oil prices from falling to further ruinously low levels. Their efforts were uneven but partially successful due to the robust demand for oil and a spate of unfortunate events in the second half of last year that disrupted crude and refined product supply. These events included the Harvey superstorm, Keystone and North Sea pipeline outages, and geopolitical disruptions in northern Iraq. The combination of these factors has mostly removed the inventory glut, enabling prices to recover from their lows.

Of course, most consumers and businesses do not see "crude oil" prices but instead are exposed to the prices of refined products such as road diesel and heating oil. Global crude oil prices, however, are the primary determinant of refined product prices. In the United States, refined product prices usually follow crude oil prices with a roughly three-week lag. Like crude oil, gasoline and diesel pump prices have also recovered.

The Oil Market is in a New Era Marked by Boom-and-Bust Price Swings

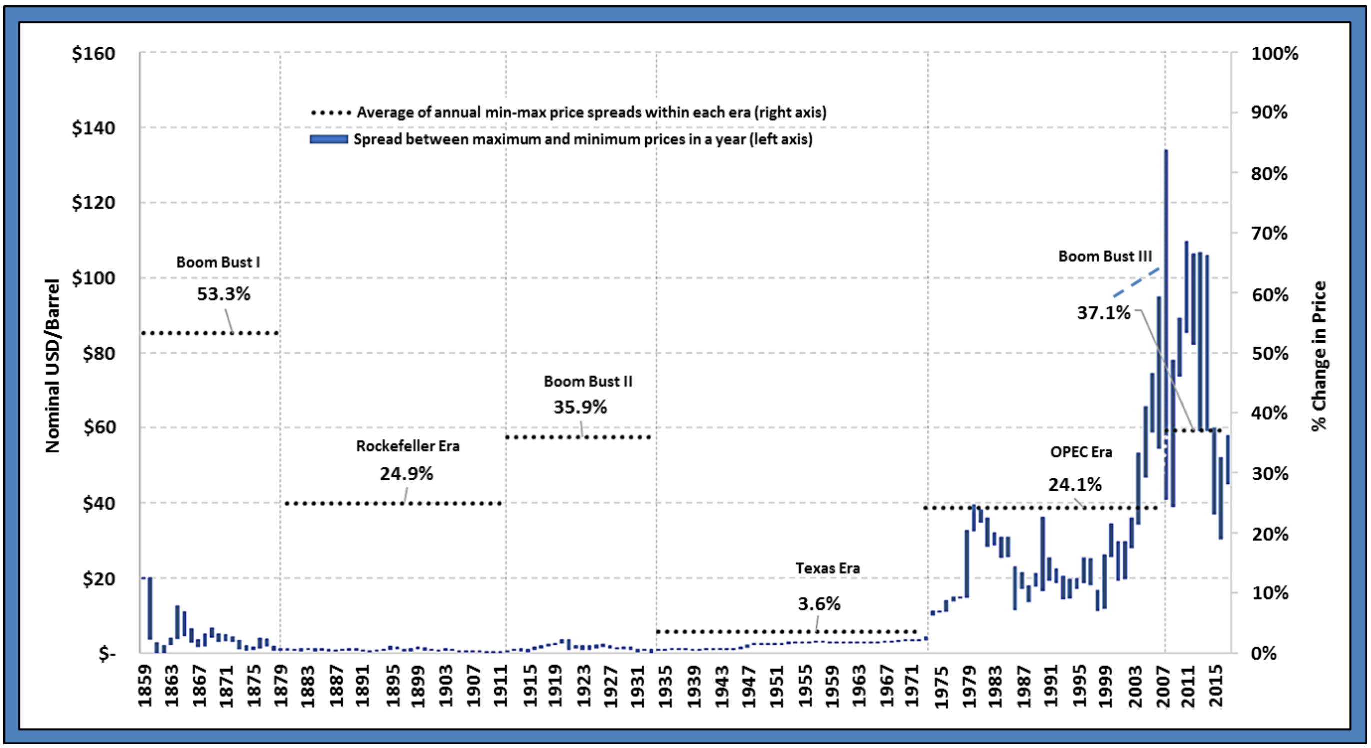
Before delving into detail about both recent and prospective oil prices, let me step back and note that crude oil prices have exhibited unusually wide swings over the last 15 years. In modern times, crude oil prices do not nearly quintuple over several years, absent a war in the Middle East. And they don't normally plunge by 60% in six months, as happened in 2014, without a recession or sudden supply surge. Oil's unusually wide swings reflect the transition from a nine-decade era of supply management to one in which there is arguably no effective supply manager (McNally, 2017).

Oil prices are unusually prone to volatility because both supply and demand are insensitive or "sticky" in responding to price changes in the short term while storage is limited and costly (McNally, 2017). Oil's notorious price volatility has troubled not only the oil industry but broader economic and governmental actors, given oil's vital importance for economic growth and security. To vanquish oil's wild swings and stabilize oil prices, governments and producers have (at least in the past) resorted to regulating crude oil production with the goal of preventing big surpluses (inventory builds) or deficits, which can result in destabilizing price busts and booms, respectively.

Unpopular boom-and-bust oil prices during the two decades following the breakup of Standard Oil in 1911 deeply rattled the country and by the early 1930s convinced the U.S. to become the world's first and most successful supply manager or "swing producer." Texas regulators, along with other oil states, the federal government, and major international oil companies, exerted strong control of production over four decades. The Texas Railroad Commission imposed quotas well-by-well, field-by-field, for forty years. The Organization of Petroleum Exporting Countries (OPEC) took over from the U.S. in the early 1970s, though not as successfully, and has been ineffective since 2008.

Figure 1 shows how crude oil price volatility has varied through history depending on whether an effective swing producer or supply manager was controlling the market.

Figure 1
Annual Ranges of Monthly U.S. Crude Oil Prices, 1859-2017



Data Sources: Rapidan Energy Group, based on *The Derrick*, American Petroleum Institute, Federal Reserve Bank of St. Louis, Energy Information Administration (EIA), and The Bloomberg.

The crude oil price bust in 2016 spawned a new group comprised of some OPEC producers (led by Saudi Arabia) and non-OPEC producers (led by Russia), which has attempted to play the role of swing producer, but its impact is limited and its future success is uncertain.

Shale Oil is Neither Swing Production nor Spare Capacity and Will Not Keep Oil Prices Stable

When in late 2014, Saudi Arabia and other OPEC producers refused to cut production under soaring U.S., Canadian, and Brazilian supply, many hoped that U.S. shale oil producers would replace OPEC as the swing producer, thereby keeping oil prices stable. These hopes were disappointed, however, and for good reason: U.S. shale oil producers are in no way a replacement for swing producers, and shale oil does not constitute the "spare production capacity" that the market has traditionally relied upon to stabilize oil prices.

Shale oil production is *more* responsive to price signals than conventional production with lead times for new supply measured in months or quarters instead of years. But shale does not respond fast and large enough to prevent global inventory imbalances and large price swings. To ensure long-term price stability, swing producers must be able, willing, and legally authorized to change oil supply in large amounts, within weeks, and for long periods of time. In some respects, swing producers are akin to central banks that control the supply of base money. The Texas Railroad Commission, the Seven Sisters oil cartel, and OPEC (mainly Saudi Arabia) all constituted genuine swing producers. Shale oil is produced by many dozens of highly idiosyncratic public and private companies, each competing with each other to maximize reserves and production. Shale producers are extremely diverse regarding resources and capital structure, they pursue growth targets instead of price stability, and they abide by punitive anti-trust laws that prevent them from even appearing to cooperate in stabilizing prices.

Shale oil production has also proven much more resilient to price declines than many expected in 2014, primarily due to a combination of widespread capital availability and efficiency gains with the latter driven by innovation and service-cost reductions.

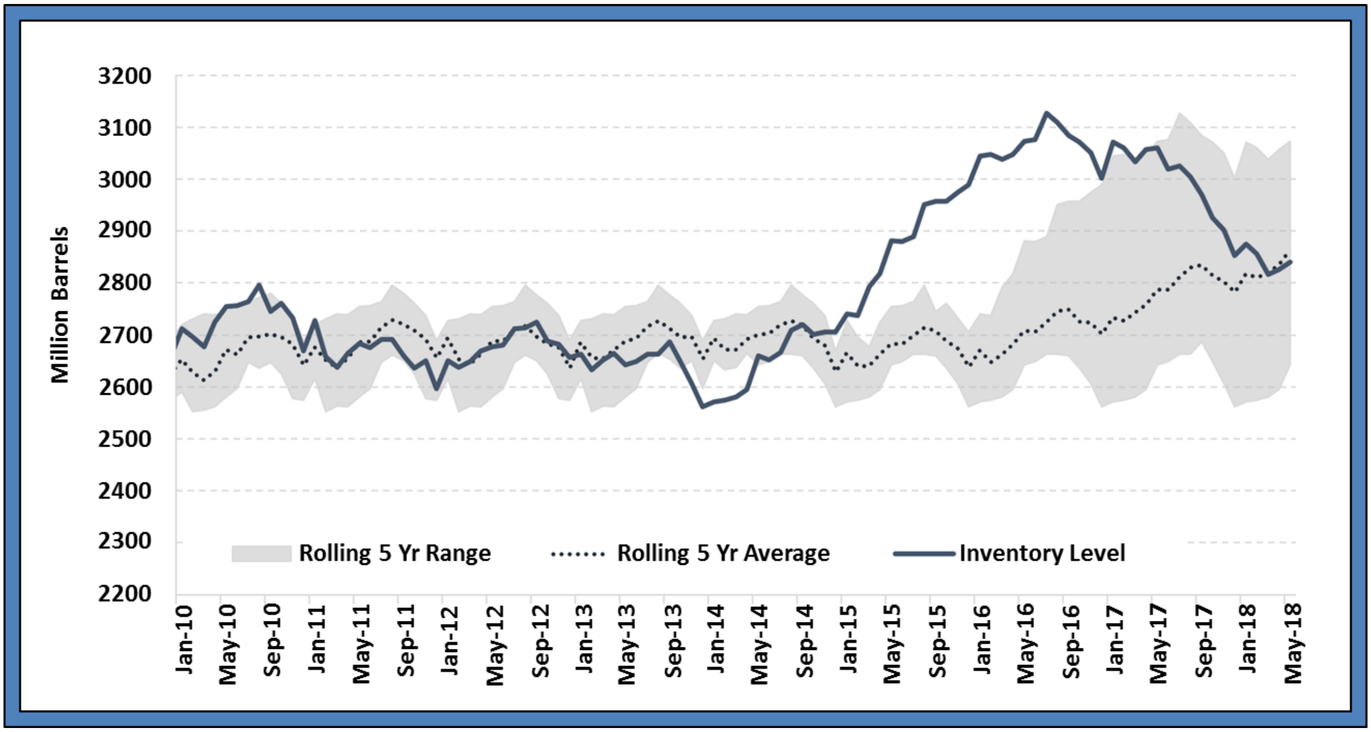
A more plausible replacement for OPEC than U.S. shale is the new entity founded by Saudi Arabia and Russia, comprising some 25 OPEC and Non-OPEC producers, which I call the Vienna Group, but is also known by "OPEC-plus" or "ROPEC." This group agreed to restrain production starting in early 2017 and, as noted above, contributed to the normalization of inventories and recovery of crude oil prices.

The jury remains out as to whether this new Saudi-Russian led entity will prove to be a successful long-term supply manager or instead join the list of *ad hoc*, temporary cartels formed after price busts but that dissolved afterward. Saudi Arabia and Russia's recent decision to maximize production despite opposition from Iran and other members of the Vienna Group will put the entity's cohesion to the test.

Commercial Inventories May Have Normalized, But the Risk of Big Crude Price Moves Remains High

Turning to the recent past, by mid-2018 the oil market shifted from oversupply to "normal," characterized by commercial inventories near their five-year range, as shown in Figure 2 on the next page. That said, the range itself has risen in recent years since the average captures the glutted levels post-2014.

Figure 2
OECD Commercial Crude and Product Inventories



Sources: International Energy Agency (IEA) and Rapidan Energy Group.

The return to normal inventories by mid-2018 was due to the following four factors:

- Oil demand generally surprised to the upside. For example, oil demand grew by nearly 1.6 million barrels per day (mb/d) last year, some 23% higher than initially projected by the International Energy Agency.

- Unexpected production outages due to geopolitical disruptions in Venezuela, Iraq, and Libya occurred.

- Large storms Harvey and Nate along with major pipeline outages in the U.S. and the North Sea in the second half of last year also took place.

- Production restraint by Saudi Arabia, Russia, and other OPEC and non-OPEC producers, starting in early 2017, took effect.

But the “normal” to which the oil market has returned is precarious and may well be fleeting. Extraordinary shifts and risks arising from supply and demand, geopolitical trends and events, and policy demands are likely to extend this 15-year old era of boom-and-bust price cycles, especially if an effective swing producer remains absent.

Looking forward, the outlook for crude oil prices resembles a “tug of war” between supply-and-demand factors that point to lower oil prices on the one hand, and geopolitical disruption risks that point to higher prices on the other hand. My firm expects geopolitical risks will keep a floor under crude prices near term, but by next year the weight of expected new supplies should exert downward pressure on prices. However, we see pronounced risks that oil prices could rise or fall much more than currently expected. A recession could lead to much lower prices while geopolitical risks and disruptions, for example in Iran, Libya, and Venezuela, could send crude oil prices back into the triple digits and prices well above $3 per gallon.

Low Spare Production Capacity and High Geopolitical Disruption Risks

With inventories back to normal and geopolitical disruption risks proliferating, a critical question becomes the amount of quickly producible oil the world can call on in case of an outage – commonly called “spare capacity.” Oil supply is vulnerable to disruptions from geopolitical conflict, storms, and accidents. The rigidity of oil demand in the short term means a supply outage can trigger large price spikes. Having a sufficient “spare capacity” buffer is critical for crude oil price stability in general and especially for preventing unexpected outages anywhere from triggering economically harmful prices spikes everywhere, including here. Former EIA Administrator Adam Sieminski has summarized academic research, which found that spare production capacity reduces oil price volatility and generates between $170 and $200 billion of annual economic benefits (Sieminski, 2018).

Genuine power in the oil market comes less from how much a country produces and instead whether it can stabilize prices and offset major disruptions. Spare capacity is one measure of that power. The U.S. and Seven Sisters cartel controlled spare capacity from 1932 until 1972. Since then Saudi Arabia has held the lion's share of spare capacity. But with the Kingdom's decision earlier in the year to surge production, it has likely approached zero spare capacity. Whether zero or extremely low, spare capacity *is* very tight. Tight spare production capacity poses a risk of oil price spikes, given the large number of disruptions and threatened disruptions present in the oil market, some of which are summarized below.

Venezuela’s production has fallen over 0.7 mb/d in the last year and is expected to continue to implode slowly. The fast exodus of workers at PDVSA (Venezuela’s national oil company), the lack of sufficient chemicals for blending and upgrading Venezuela’s heavy crude oil, and PDVSA’s severe cash constraints will continue to drive production lower. Prospects for a recovery in oil production are bleak – even if President Maduro were to leave office tomorrow, Venezuela would struggle to boost production back to previous levels.

By contrast, Libya has seen sharp, but so far temporary disruptions as armed factions (both local and national) seek to gain leverage ahead of expected elections later this year, keeping production in a 0.8-1.0 mb/d range. In western Libya, the lack of a unified security force exposes oil facilities to attacks by militias seeking to extract payoffs, contracts, and other resources from the national oil company and the government in Tripoli. In the east, oil production that was relatively stable under the control of the Libyan National Army (a coalition of eastern militias fighting under the command of General Khalifa Haftar) is likely to be increasingly rattled as Libya’s most significant actors jostle for power.

As of the writing of this article, the oil market is grappling with a new disruption risk in the form of the loss of a large amount, if not all, of Iran's 2.5 mb/d of exports. Uncertainty about how sanctions might impact Iran's oil exports arises from several factors:

- There is market uncertainty about the number of exemptions that the Trump administration will grant over time, and for how long, to Iran's current importers.

- It is unclear whether Chinese, Indian, and other state-owned oil companies may increase imports to offset losses from other customers wary of violating U.S. sanctions.

- It is not known whether Iran will choose to escalate tensions by eventually resuming enrichment or threatening safe passage of the roughly 19 mb/d that passes through the Strait of Hormuz, the world's most important choke point.

Looming Regulations on Marine Fuel Sulfur Limits Could Roil the Oil Market Next Year

Oil is bound up with many policy debates and discussions, from climate change to ethanol and fuel economy standards. But one important policy issue preoccupying the oil industry and likely to impact oil prices has so far gone largely unnoticed in Washington: there will be a mandatory reduction in sulfur limit emissions for ocean-going ships starting on January 1, 2020, commonly referred to as "IMO 2020." IMO 2020 is expected to reverberate onshore and impact consumer oil prices, especially for trucking and airline companies as well as home heating oil consumers. The International Energy Agency referred to IMO 2020 as "easily the most dramatic change in fuel specifications in any oil product market on such a large scale," according to *Financial Times* (2017).

By way of brief background, in October 2016 the United States along with other nations participating in the U.N. International Maritime Organization (IMO) confirmed an earlier, tentative decision to implement a reduction in the sulfur content of the fuel used in ships on the high seas ("marine bunkers") from 3.5% to 0.5% sulfur as of January 1, 2020. Ship owners have two main compliance options to meet the looming regulations.

First, ships could continue to burn high-sulfur fuel but install exhaust gas cleaning systems commonly called "scrubbers" to remove sulfur from the ship's emissions. Only a small fraction of ships have installed scrubbers however and insufficient time remains to install many more before the deadline. Therefore, most will opt for a second option, to switch from high-sulfur, heavy fuel oil to lower sulfur, heavy fuel oil or middle distillates (which are also referred to as "gasoil" or "diesel.")

A major question hovering over the market is whether a big new demand wave for low-sulfur distillate from shippers would overwhelm the refining industry's ability to supply it while meeting demand needs by other users such as motorists, airlines, and home heating oil consumers. While IMO had considered a 2025 implementation date, the decision taken in 2016 to start in 2020 was backstopped by a report commissioned by IMO that found "the refinery sector has the capability to supply sufficient quantities of marine fuels with a sulfur content of 0.5% or less ... while also meeting demand for non-marine fuels" (CE Delft *et al.*, 2016). A rival study, in turn, commissioned by shipping and oil industry groups in 2016, and updated this year, concluded that implementation of IMO regulations in 2020 could lead to spikes in petroleum-complex prices during a "scramble period" (*The Motorship*, 2018).

Indeed, as the IMO 2020 deadline fast approaches, leading official forecasters and private sector experts expect implementation will trigger a large spike in the price of crude oil and refined products, particularly for "middle distillate" fuels. IEA (2018) concluded that the *global* refinery system would not be able to produce a sufficient amount of low-sulfur fuels in 2020 and at least for a few years afterward. As a result, shippers facing a new IMO mandate will bid low-sulfur distillate away from the other users mentioned above. The IEA expects the scramble for clean distillate could trigger a 20 to 30% spike in the price of heating oil and diesel fuel. Further, this "sharp increase in the price of [distillate] following the 2020 IMO changes [would] penalize demand in other sectors," noted IEA (2018).

Moreover, the IEA has warned that IMO 2020 could push up global crude oil prices and therefore pump prices:

> A worrying number of refiners, including large integrated oil companies, have publicly stated that one of their options to meet the new sulfur specification would be to use lighter and sweeter crude oil that requires less intensive hydrotreatment. As the two important futures benchmarks, Brent and WTI, are based on light sweet crude oil output, the increased demand for this type of crude oil may fuel a sharp increase in futures prices, with consequences felt across all product markets (IEA, 2018).

Benefits and Winners from Lower Sulfur Limits in Marine Fuels

There will be clear environmental and human health benefits from reducing sulfur emissions from ocean-going ships. And domestic, deep conversion refiners will benefit from their competitive advantage regarding the production of lower sulfur fuels. If, as the IEA cautioned above, IMO 2020 also boosts lighter crude oil prices, our domestic producers will benefit. Longer term, low-sulfur regulations could also enable liquefied natural gas to see wider use as a bunker fuel.

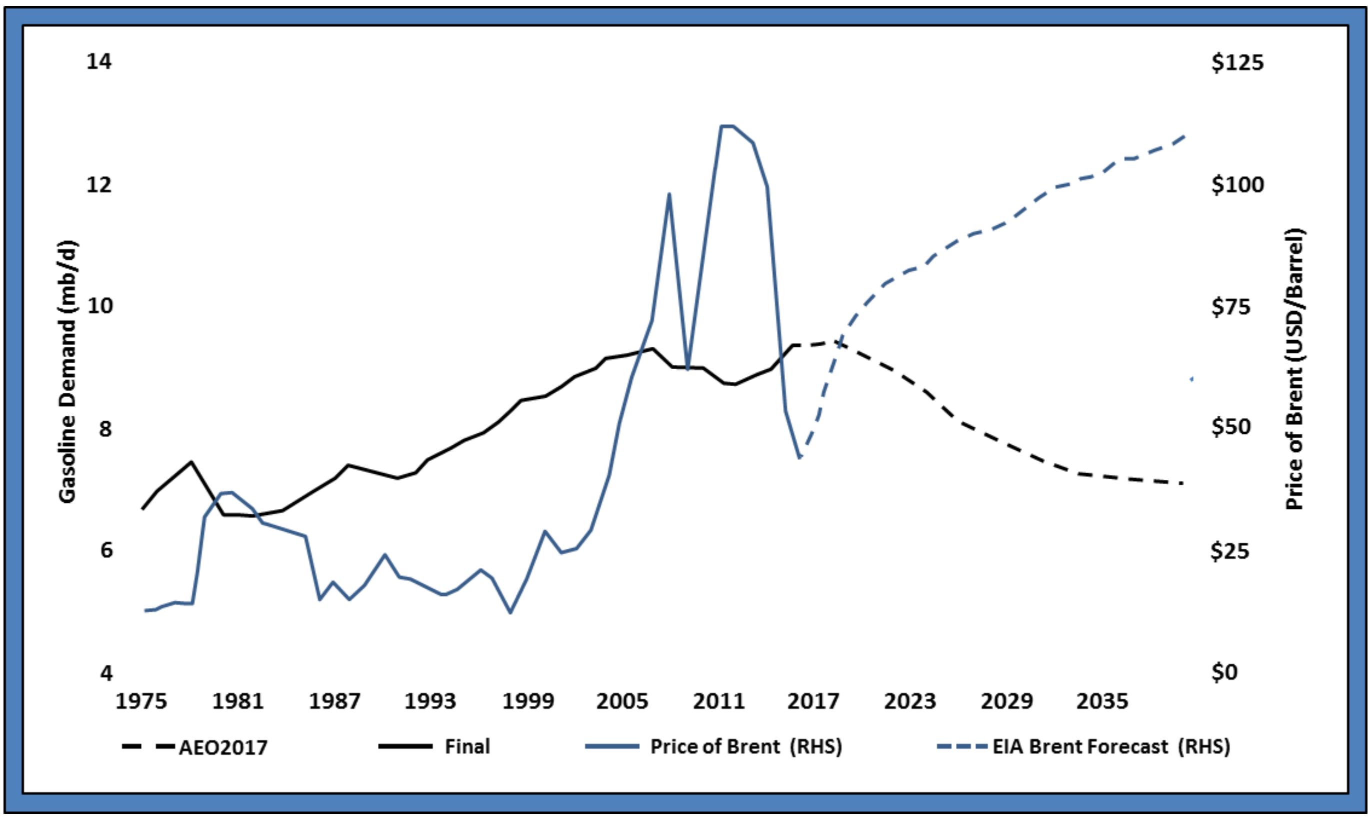
If Policy-Driven Peak Demand Disappoints, Oil Prices Will Rise Sharply

Lastly, a crucial factor driving longer-term oil prices is the outlook for oil demand growth in transportation. Transportation accounts for 56 percent of global oil demand though petrochemicals are an important growth sector for oil use (IEA, 2016). Oil market participants and analysts have been preoccupied with the future rapid displacement of oil in transportation due to policies aimed at increasing efficiency or non-petroleum transportation fuels, primarily via electric vehicles (EVs). An interesting aspect to this debate – referred to as "peak demand," "energy transition," or "decarbonization" of transportation – is the role that autonomous vehicles (AVs) may play in future oil demand.

Leading official forecasts, from both the EIA and IEA, assume decarbonization policies will significantly curtail future oil demand growth. For example, both the EIA and IEA assume that U.S. gasoline demand will peak this year and then decline sharply in coming years and decades, largely due to federal fuel economy regulations and California's Zero Emission Vehicle (ZEV) Mandate. The EIA's predictions are illustrated in Figure 3 below. Notably, the peak and decline in U.S. motor gasoline demand that the EIA forecasts would be the first to occur without a recession.

There are good grounds for caution that we will see such a big, imminent "policy peak" in gasoline demand in the United States. In the past, the EIA had predicted peak gasoline demand in the 1980s after a big oil price run up and implementation of federal fuel economy standards. But lower oil prices, strong consumer preference for larger vehicles, and accommodative public policies (including the federal government easing Corporate Average Fuel Economy (CAFE) rules in the late 1980s and mid-1990s) ended up proving these forecasts premature. My firm studied the U.S. CAFE and California ZEV programs last year and concluded, for largely the same reasons, that they are unlikely to drive a peak in U.S. gasoline demand in coming years (Rapidan Energy Group, 2017).

Figure 3
EIA Annual Energy Outlook (AEO) Gasoline Demand vs. Oil Prices (Including Predictions), 1975 – 2040



Source: Chart based on EIA AEO.

Whether or not U.S. gasoline demand peaks in the coming years will resonate globally. The U.S. gasoline demand market is massive – accounting for nearly one in ten barrels per day consumed on the planet – and it enjoys symbolic importance among leading energy media, forecasters, and analysts. My firm also tracks decarbonization policies around the world, particularly those impacting transportation, and took a hard look at the top 20 most material of such policies – from 9 countries accounting for 57 mb/d or 58%

of global oil demand. What we found is that when accounting for the realities of actually implementing these policies like the U.S. CAFE program – the use of credits, different testing procedures, and other features that reduce stringency – those policies only resulted in about 53% of the demand destruction assumed "on paper" by the regulations.

Automated Vehicles Could Significantly Boost *or* Reduce Oil Demand

National Renewable Energy Laboratory (NREL) researchers have noted that AVs could have a "wide range of possible energy impacts" (Brown *et al.*, 2013). Energy impacts of widespread AV adoption are highly uncertain with estimates ranging from a 60 percent decline to a 200 percent increase (Chase, 2018). Factors that could increase energy demand include ease of travel, lower perceived and actual cost per mile, and underserved populations obtaining travel services.

But whether mass adoption of AVs would increase or decrease oil demand depends largely on which fuels – oil or electricity – AVs will use. Many assume that AVs will be EVs. If so, oil demand growth would sharply slow. But if widespread AV adoption occurs before EVs proliferate, then oil demand could increase significantly. For example, a 2014 NREL study found that mass adoption of conventionally powered AVs could have the "unintended consequence" of doubling fuel demand (Brown *et al.,* 2014). More recently, a 2016 NREL study found that widespread AV adoption could *triple* U.S. gasoline consumption from current levels of 9.3 mb/d (2017 average), assuming a fully autonomous fleet, petroleum-fueled vehicles, $3 gasoline and current fleet-wide efficiency (Stephens *et al.*, 2016).

If future global oil demand turns out to be stronger than many governments and companies currently expect, oil prices would be higher than currently anticipated. Strong demand would then collide into insufficient investment in oil production.

While a recession could send oil prices lower, I expect the next boom phase in oil prices will arise due to faster-than-expected demand, both because policies will turn out weaker than expected and because the recent bust has encouraged demand while hampered investment in new oil fields and production facilities. Again, oil's demand rigidity means price increases could be significant. And with spare production capacity wafer thin, geopolitical disruption risks could be expected to eventually result in further oil price spikes.

Conclusion

In 2012 I had the honor of testifying before the U.S. House of Representatives Small Business Committee. At the time, I noted that crude oil, and therefore pump prices, had entered a new "Space Mountain" era of boom-and-bust price cycles (McNally, 2012). I continue to maintain that view. If a new swing producer does not emerge, we should all buckle up for a continued, roller-coaster ride on "Space Mountain."

Endnote

This commentary is based on McNally (2018).

References

Brown, A., Repac, B. and J. Gonder, 2013, "Autonomous Vehicles Have a Wide Range of Possible Energy Impacts," National Renewable Energy Laboratory (NREL) Poster at a Workshop on Road Vehicle Automation, Stanford, July 16. Accessed via website: https://www.nrel.gov/docs/fy13osti/59210.pdf on October 15, 2018.

Brown, A., Gonder, J. and B. Repac, 2014, "An Analysis of Possible Energy Impacts of Automated Vehicles," in G. Meyer and S. Beiker (eds) Road Vehicle Automation (Lecture Notes in Mobility), Cham: Springer, pp. 137-153.

CE Delft, Stratas Advisors, UMAS, NMRI, Petromarket Research Group and S. Hanayama, 2016, "Assessment of Fuel Oil Availability, Final Report," July. Accessed via website: https://www.cedelft.eu/publicatie/assessment_of_fuel_oil_availability/1858 on October 15, 2018.

Chase, N., 2018, "Automation Vehicles: Uncertainty and Energy implications," Presentation at the 2018 EIA Energy Conference, June 5. Accessed via website: https://www.eia.gov/conference/2018/pdf/presentations/nicholas_chase.pdf on October 15, 2018.

Financial Times, 2017, "New Shipping Fuel Regulation Set to Hit Commodities," May 30.

[IEA] International Energy Agency, 2016, "World Energy Outlook 2016," November 16.

IEA, 2018, "Oil 2018: Analysis and Forecasts to 2023," March 5.

McNally, R., 2012, "'Space Mountain' Pump Prices," Testimony to the U.S. House Committee on Small Business," May 9. Accessed via website: https://smallbusiness.house.gov/uploadedfiles/mcnally_testimony.pdf on October 15, 2018.

McNally, R., 2017, Crude Volatility: The History and the Future of Boom-Bust Oil Prices, New York: Columbia University Press.

McNally, R., 2018, "Factors that are Impacting Global Oil Prices," Testimony to the U.S. Senate Committee on Energy and Natural Resources," July 24. Accessed via website: https://www.energy.senate.gov/public/index.cfm/files/serve?File_id=8E497B21-BD5F-4340-990E-27B27AD2F9B4 on October 15, 2018.

Rapidan Energy Group, 2017, "Peak U.S. Gasoline Demand is a Mirage," Proprietary Analysis, July.

Sieminski, A., 2018, "The $200 Billion Annual Value of OPEC's Spare Capacity to the Global Economy," *Global Commodities Applied Research Digest*, Industry Commentaries, Vol. 3, No. 2, Winter, pp. 88-91.

Stephens, T., Gonder, J., Chen, Y., Lin, Z., Liu, C. and D. Gohlke, 2016, "Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles," NREL Technical Report, November. Accessed via website: https://www.nrel.gov/docs/fy17osti/67216.pdf on October 15, 2018.

The Motorship, 2018, "'Major Risks Remain' As Sulphur Cap Nears," June 28. Accessed via website: http://www.motorship.com/news101/fuels-and-oils/major-risks-remain-as-sulphur-cap-nears,-study-finds on October 15, 2018.

Author Biography

ROBERT McNALLY
Founder and President, Rapidan Energy Group

Mr. Robert McNally is the founder and President of Rapidan Energy Group, an independent energy consulting and market advisory firm based in the Washington, D.C. area. Mr. McNally's clients include leading global energy market investors, producers, and traders. Mr. McNally's 26-year professional career includes senior financial market and official posts spanning economic, security, and environmental aspects of energy market analysis, strategy, and policymaking. Mr. McNally started his professional career in 1991 as an oil market analyst and consultant with Energy Security Analysis, Inc. In 1994, he joined Tudor Investment Corporation and for twelve subsequent years analyzed energy markets, macroeconomic policy, and geopolitics for Tudor portfolio managers, earning promotions to Vice President and Managing Director. From 2001 to 2003, Mr. McNally served as the top international and domestic energy adviser on the White House staff, holding the posts of Special Assistant to the President on the National Economic Council and, in 2003, Senior Director for International Energy on the National Security Council.

Mr. McNally earned his double major B.A./B.S. in International Relations and Political Science from American University and his M.A. in International Economics and American Foreign Policy from Johns Hopkins' Paul H. Nitze School of Advanced International Studies (SAIS). He was co-chair for energy policy on the 2008 Romney Presidential Campaign, served on the Policy Advisory Committee for Senator Marco Rubio's 2010 Senate campaign, and regularly advises congressional and administration officials on energy policy and markets. Mr. McNally is a Member of the National Petroleum Council and is a non-resident fellow at Columbia University's Center on Global Energy Policy.

Mr. McNally has testified to the House and Senate on energy markets and national security and speaks to professional conferences on energy markets, policy, and geopolitics. He has been published in *Foreign Affairs* (co-authored essay with Michael Levi, July/August 2011) and has been interviewed by CNN, *The Economist, Fox Business, The Financial Times, The Washington Post, National Journal,* Platts Energy Week TV, PBS' "Great Decisions in Foreign Policy" series, *Bloomberg News*, *Aviation Daily* and other programs and journals. He is the author of the acclaimed and award-winning 2017 book, Crude Volatility: The History and the Future of Boom-Bust Oil Prices, published by Columbia University Press.

The New Geopolitics of Natural Gas

Agnia Grigas, Ph.D.
Nonresident Senior Fellow, Atlantic Council; and Board Member, LITGAS

In June 2018, **Dr. Agnia Grigas** (right)**,** Ph.D., nonresident Senior Fellow, Atlantic Council and Board Member, LITGAS, participated in the World Gas Conference in Washington, D.C. where she discussed her book, "The New Geopolitics of Natural Gas." To Dr. Grigas' left is Mr. Robert McNally, Founder and President of the Rapidan Energy Group, whom, in turn, also contributed an article to this issue of the *GCARD*.

Over the last decade, developments in the natural gas markets have ushered in a transformation of the geopolitics of gas by reorienting the relationships between natural gas exporting, importing, and transit states. Understanding the landscape of the evolving natural gas market illuminates the changing rules of natural gas trade as well as bilateral and multilateral relations between states, many of which see natural gas as a strategic resource and even a tool of foreign policy. My newest book, The New Geopolitics of Natural Gas (Harvard University Press, 2017), explores this energy revolution, which is driven by the shale boom, the surge of liquefied natural gas (LNG) trade, the rise in interconnective gas infrastructure, and the growing global demand for natural gas as a cleaner fossil fuel. The book focuses on the key regions that are driving a shift in global gas supply and demand: United States, the rising gas exporter; Russia, the traditional gas exporter; Europe, the traditional gas importer; developing Asia, the growing demand center; as well as other transit and supply countries in Eurasia.

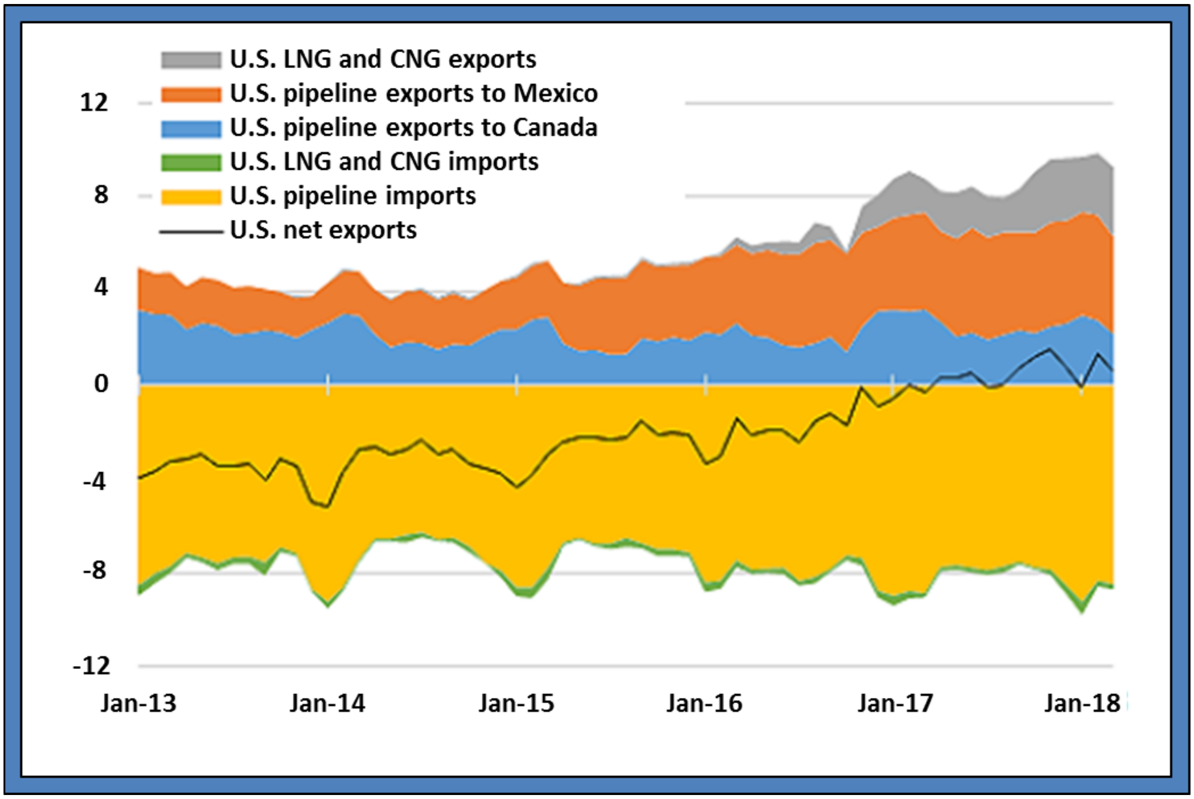
The New Geopolitics of Natural Gas is structured by my proposed analytical framework for the study of the politics of energy. Gas producing and exporting states engage in the *politics of supply*, which can enable a producing or exporting state to pursue export policies from its position of relative strength vis-a-vis the gas consumer. These exporters have the ability then to enhance their national, economic, political, and security interests by policies such as flooding or starving the market, favoring allies, or punishing enemies via pricing or supply policies. Gas importing countries can fall into the *politics of demand* or *politics of dependence* subject to their level of diversification, volumes of imports, and market conditions. Importers stuck in the *politics of dependence* are disproportionately reliant on a particular gas producing state(s) with limited political and economic options available, and thus often operate from a position of weakness vis-a-vis the gas supplier. In contrast, states that can leverage their sizable gas demand vis-à-vis a number of diversified suppliers can be described as utilizing their *politics of demand*. The *politics of transit* describes the dynamics for gas transit states whose territories are essential for the flow of energy supplies from producing states to importing states. Transit states have traditionally featured land-based pipelines, but the introduction of LNG to the market has added the element of international waters to the equation. These states have some leverage and negotiating power vis-a-vis both exporting and importing states, but can fall into the trap of becoming "rentier states." Finally, we have the *politics of interdependence*, between importing and exporting states where there is equal interdependence between the two. None of the categories above are mutually exclusive: oftentimes, a state can be evaluated through multiple categories depending on the circumstances. My book seeks to address the geopolitics of the natural gas market through these lenses and demystify the complex economic, political, and security relations that stem from the natural gas market.

The United States is at the lead of the market transformation as its unconventional shale gas development has made it the world's largest natural gas producer in 2011 and a rising LNG exporter. Other conventional energy powers, particularly Russia, continue to rely primarily on piped natural gas exports to the markets of its energy-poor neighbors in Europe and Eurasia. However, the shale boom and influx of LNG into the global gas market is beginning to provide viable energy alternatives for these consumer states. Amidst fraught U.S.-Russia relations, competition over natural gas markets in Europe and Asia has come to the forefront of bilateral relations. On the other hand, China is continuing to build upwards and outwards, consuming more and more energy as it does and seeking to reduce consumption of coal in favor of natural gas to address domestic pollution. As the drivers of global energy demand going forward, China and the other rising Asian powers such as India stand to dictate some of the rules of the new order of the global gas market. In my book, I explore the nature of the market changes, the US' new energy clout from LNG, the politics of supply for Russia and Gazprom, the politics of dependence in Europe, the limitations on isolated suppliers in Eastern Europe and Central Asia, and the power of demand in Asia. The profound implications of the changing global gas markets will leave their mark on global geopolitics.

Marked by the so-called Shale Revolution that unlocked the production of unconventional gas in North America, coupled with the growth of global LNG trade and the continued buildup of natural gas infrastructure, the gas market itself no longer looks like that of the 1990s or early 2000s. The gas trade itself is increasingly shifting from long-term contracts that locked consumers into set relationships and prices to short- and shorter-term contracts and spot trades. Furthermore, gas pricing is increasingly hub-based, as opposed to traditionally-preferred oil-based pricing. Destination clauses that hindered the re-export of natural gas across state borders have been eliminated in the European Union and are not pursued by American LNG exporters. Liquidity, flexibility, and optionality mark today's markets while some even discuss a "gas glut." These shifts illustrate that the natural gas market is moving towards a buyers' market when it has traditionally been the exporters that established the terms of the trade.

Despite the accruing benefits for gas importers, the U.S. has emerged as a global energy superpower due to these shifts in the energy markets. In 2016, the U.S. launched its LNG exports and it is poised to become the world's third largest LNG exporter by 2020, just behind Australia and Qatar, according to EIA (2018). Emerging as a global gas leader, the U.S. has increased its energy diplomacy potential. The combination of shale gas production and LNG exports has given the U.S. a solid position as a newly exporting state and many first-mover advantages in the globalizing gas markets. The first quarter of 2018 saw the U.S. become a net exporter of natural gas for the first time since 1957. The EIA projects that U.S. natural gas exports will only continue to increase. Figure 1 on the next page illustrates the recent trend in natural gas exports.

Figure 1
U.S. Natural Gas Imports and Exports
(Billion cubic feet per day)



Note: A minor fraction of Canadian exports and imports consists of compressed natural gas (CNG).

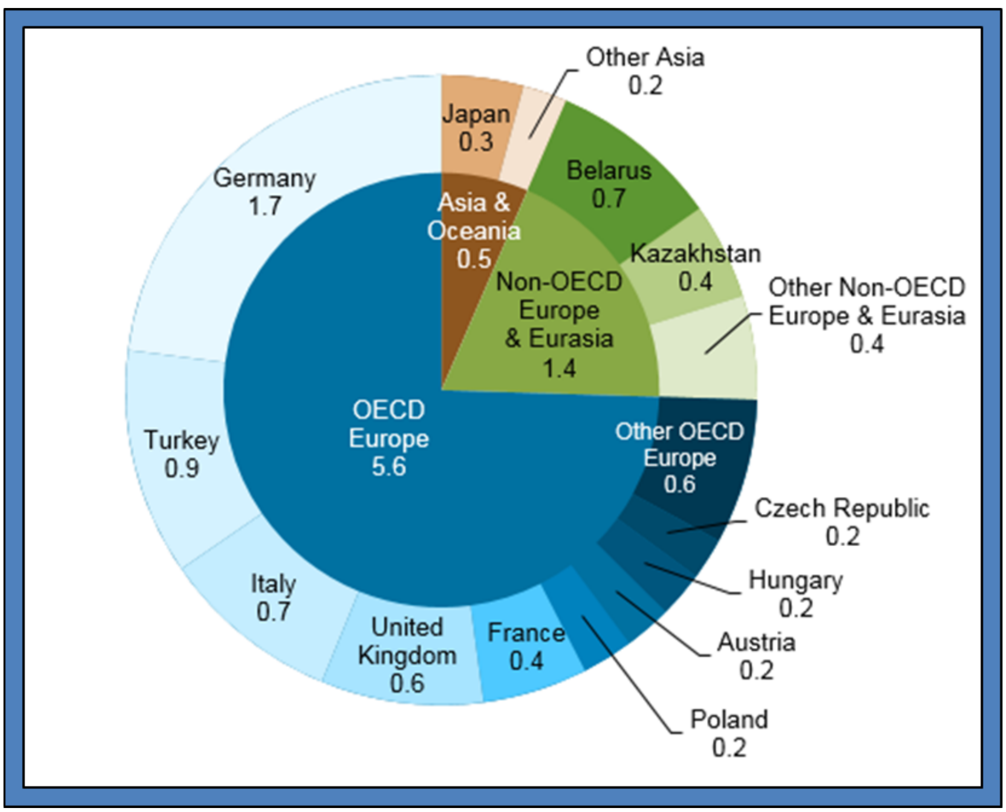
Source: U.S. Energy Information Administration's *Natural Gas Monthly*.

On the other side of the spectrum, there is Russia, a traditional natural gas export powerhouse. Soviet and then Russian gas has been exported by pipeline to Western European states since the late 1960s and early 1970s. Russia's state-owned gas company, Gazprom, has served to implement the Kremlin's gas diplomacy and even gas weaponization vis-a-vis many of Russia's neighboring states. Since the early 2000s, Gazprom has helped shape foreign policy, taking such measures as cutting off gas supplies to Ukraine in 2005, 2009 and again in 2014, which has impacted gas volumes delivered to European customers. Gazprom has also politicized the pricing of its gas, offering far lower prices to large Western European consumers and obedient allies like Belarus than countries like the Baltic States or Ukraine, with which Russia has had numerous political and gas disputes. Nonetheless, due to its geographic proximity and existing pipeline infrastructure, Russian gas remains in high demand in Europe and beyond.

Russia's monopolist position and political leverage over its key natural gas market of Europe is eroding due to the abovementioned market changes. In 2017, the American LNG company, Cheniere Energy, Inc., delivered its first shipments of LNG to both Poland and Lithuania, marking a symbolic turning point in that region's energy independence and security (Grigas, 2017). LNG import capability have allowed countries like Poland and Lithuania to diversify their import sources and routes, have boosted their energy security, and reduced Gazprom's ability to strong-arm them in energy relations while simultaneously reducing the Kremlin's clout in the region.

However, Russia will not give up its markets without a fight. Europe has been the primary destination for Russia's gas exports – in 2016, approximately 75% of its gas exports were destined for OECD Europe; please see Figure 2. Germany and Turkey remain the largest markets for Gazprom's exports. The Russian-led Nord Stream II Pipeline, which seeks to boost Russian gas exports to Germany via a new pipeline under the Baltic Sea, would cement Russia's hold on the European gas market, and particularly German market, all while bypassing Ukraine and depriving Kyiv of critical transit fee income (Grigas, 2018). Critics of the pipeline point to the increase of LNG in Europe as an alternative to Russian gas. The United States has even threatened to include companies involved in the project in its Russia-related sanctions. Russia is simultaneously pursuing the TurkStream Pipeline, which would boost exports to Turkey and could access the Southeast European market. Both pipelines reflect Russia's efforts to consolidate its control over the European gas market, even while the European Union's energy security strategy continues to push for diversification.

Figure 2
Russia's Natural Gas Exports by Destination, 2016
(Trillion cubic feet)



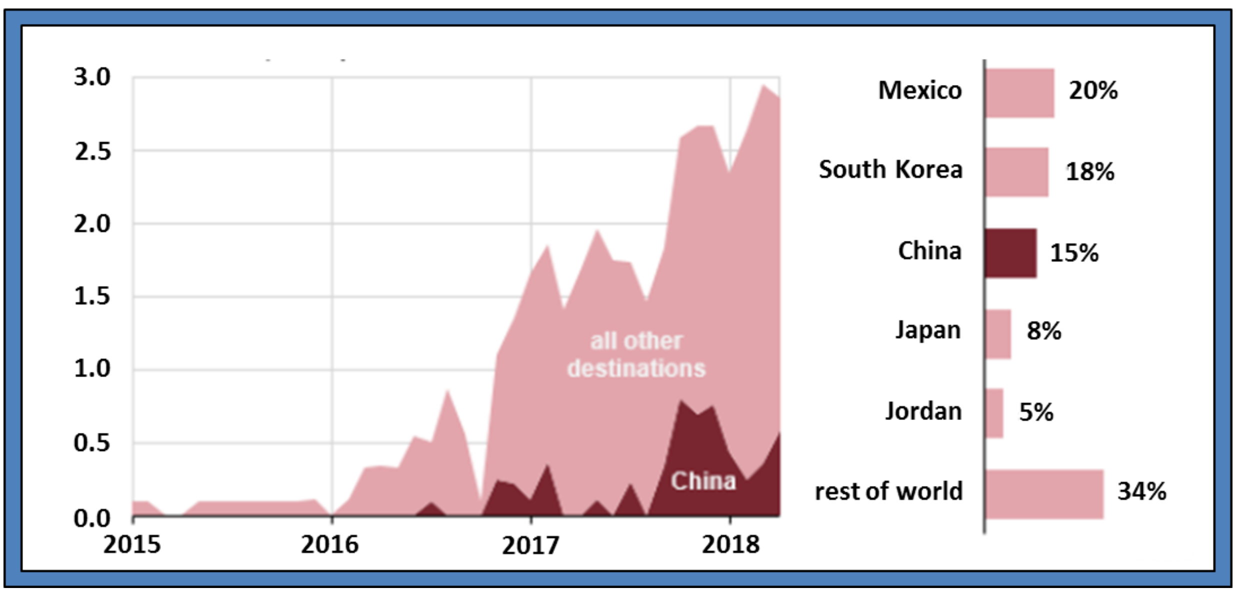
Source: U.S. Energy Information Administration, based on Russian export statistics and partner country import statistics, Global Trade Tracker.

As the new global centers for demand, the Asian gas markets are booming and developing. Today's top five LNG buyers are all in Asia: Japan, China, South Korea, India, and Taiwan. These countries accounted for almost two-thirds of global LNG demand in 2015, and are expected to import more than half of the U.S. LNG capacity between 2016 and 2019. Already, South Korea is the 2nd largest buyer of U.S. LNG, followed by China and Japan; please see Figure 3. The Asian cases represent a change in the traditional gas market. China's gas consumption increased nearly ten-fold between 2000 and 2016, outpacing the amount of natural gas produced by 2007 and becoming a net natural gas importer; please see Figure 4 on the next page. China possesses the world's largest estimated shale reserves and is one of the four countries in the world that have hydraulic fracturing programs. Yet, China's appetite for gas is only expected to grow. Unlike European states, China has carefully managed its energy policies and limited vulnerabilities arising from dependence on natural gas imports. Rather, China has used the sheer amount of gas imports it requires as bargaining leverage and power over its numerous and well-diversified supplier states. It imports gas both by pipeline and via LNG from Central Asia, Myanmar, Russia, the U.S., Australia, Qatar, Nigeria and others. China remains a "wildcard" in the gas market, given that the actual percentage of gas consumption in its overall energy mix is still quite low and there are competing forecasts on how much and how fast this percentage will rise. However, considering that China continues to promote natural gas as a key fuel, its potential to be a major force in the gas market is substantial. The EIA predicts that China will emerge as a key gas buyer before 2021 as it looks for ways to replace coal with natural gas. India is another country to watch and one that will also be one of the drivers of future global gas demand.

Figure 3

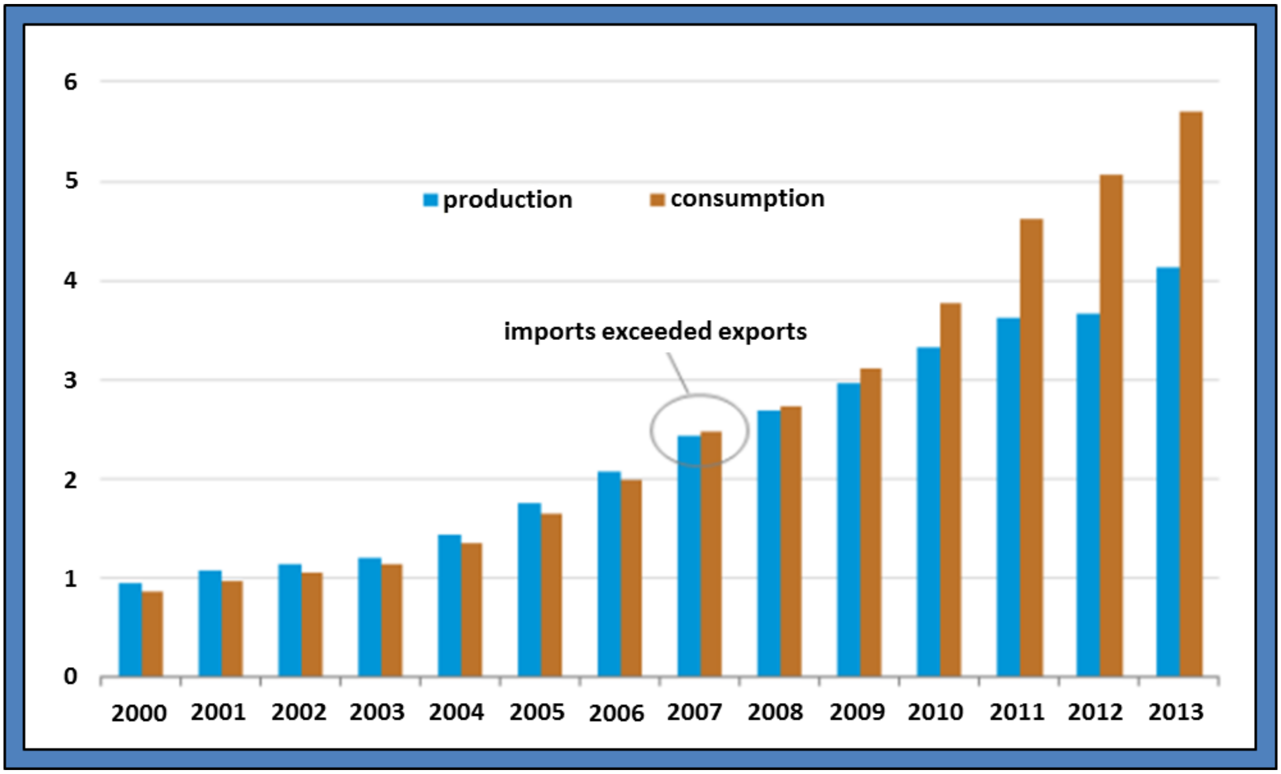
U.S. Liquefied Natural Gas (LNG) Exports (Jan 2015 - Apr 2018)
(Billion cubic feet per day)

Share of 2017 LNG Exports



Source: U.S. Energy Information Administration.

Figure 4
China's Natural Gas Production and Consumption, 2000 - 2013
(Trillion cubic feet)



Source: U.S. Energy Information Administration, *International Energy Statistics.*

In light of these changes, the debate continues around whether a global gas market has already emerged. There are outstanding questions of whether the nature of gas itself prevents it from being a truly liquid, global commodity and to what extent piped gas can compete against LNG. As I affirm in my book, I believe that the natural gas market is more global than ever before with regional markets becoming increasingly interconnected and with the disappearance of regional price differentials other than the cost of gas transport. As gas becomes more global, we are seeing a de-politicization of the gas trade. Individual countries, whether they are importers or exporters, have more optionality and flexibility in their gas trade than in the past when gas was a regionally traded commodity often doled out by monopolist companies.

Do these changes mean that the gas market will see more stability in the future? I believe so. The globalization of gas markets and the transformations underpinning it will bring long-term stability to the market due to greater liquidity and optionality. Nonetheless, the emergent interconnectivity will increase opportunities for day-to-day market fluctuations since developments in one market can now more easily impact other markets. Even with these benefits from a globalizing gas market, challenges and risks still remain. In our digitized world, the globalized gas market is more susceptible than ever to digital threats from malicious actors. The growth of LNG in the overall gas trade means that pipelines are no longer the only vulnerable point of gas infrastructure and trade. Ports, sea routes, terminals, and tankers now need to be secured as well, physically and digitally. Furthermore, the weaponization of information will continue to pose global challenges, including for the gas market. False or misleading information relating to the energy markets can be used as part of a propaganda campaign to influence local, state, regional and institutional decision-making vis-à-vis energy policy. These risks should be taken into account, as we continue to watch the natural gas trade develop and globalize.

References

Grigas, A., 2017, "U.S. Natural Gas Arrives in Lithuania," *Foreign Affairs Magazine*, September 12. Accessed via website: https://www.foreignaffairs.com/articles/baltics/2017-09-12/us-natural-gas-arrives-lithuania on October 19, 2018.

Grigas, A., 2018, "Commentary: How to Derail Russia's Energy War," *Reuters*, March 14. Accessed via website: https://www.reuters.com/article/us-grigas-russia-commentary/commentary-how-to-derail-russias-energy-war-idUSKCN1GQ290 on October 19, 2018.

[EIA] U.S. Energy Information Administration, 2018, "U.S. Liquefied Natural Gas Exports Quadrupled in 2017," *Today in Energy*, March 27. Accessed via website: https://www.eia.gov/todayinenergy/detail.php?id=35512 on October 19, 2018.

Author Biography

AGNIA GRIGAS, Ph.D.
Nonresident Senior Fellow, Atlantic Council; and Board Member, LITGAS

Dr. Agnia Grigas specializes in energy and security policy. She has authored three critically-acclaimed books: The New Geopolitics of Natural Gas (Harvard University Press, 2017), Beyond Crimea: The New Russian Empire (Yale University Press, 2016), and The Politics of Energy and Memory between the Baltic States and Russia (Routledge 2013/2016). Currently, she is a nonresident Senior Fellow at the Atlantic Council, a board member of LITGAS, and an Associate with Argonne National Laboratory. With fifteen years of experience as a business development and political risk advisor, Agnia has consulted in both the public and private sectors, including having served as an advisor to the Lithuanian Ministry of Foreign Affairs. She started her career at J.P. Morgan as a financial analyst and subsequently worked for companies such as Eurasia Group and Barclays Bank. She holds a Doctorate and Master's in International Relations from the University of Oxford, United Kingdom (Brasenose and St. Antony's Colleges) and a B.A. in Economics and Political Science from Columbia University in New York. Learn more by following her @AgniaGrigas and at www.grigas.net

EDITORIAL ADVISORY BOARD MEMBER NEWS

The Dynamics of Oil, Natural Gas, and Liquefied Natural Gas Markets

Dr. Thomas K. Lee, Ph.D., presenting on "Oil Market Dynamics and the Short-Term Outlook," during the August 2018 international commodity symposium at the University of Colorado Denver Business School's J.P. Morgan Center for Commodities (JPMCC).

Dr. Thomas K. Lee, Senior Economist in the Office of Energy Markets and Financial Analysis at the U.S. Energy Information Administration (EIA) and Member of the *GCARD*'s Editorial Advisory Board, organized the EIA's 2018 Workshop on Financial and Physical Energy Market Linkages, which took place on September 27, 2018 in Washington, D.C.

This workshop focused on the "Dynamics of Oil, NG, and LNG Markets." The workshop's academic and practitioner participants included five members of the J.P. Morgan Center for Commodities' Research Council, who participated in the workshop as follows (and are listed in alphabetical order): (1) Dr. Craig Pirrong, Professor of Finance at the University of Houston, presented on "Liquefying a Market: The Transition of LNG to a Traded Commodity"; (2) Dr. Bluford Putnam, Chief Economist at the CME Group, discussed "Energy Market Dynamics: Investments, Trading and Prices Interactions"; (3) Ms. Hilary Till, the JPMCC's Solich Scholar and Contributing Editor of the *GCARD*, participated as a discussant at the workshop; (4) Dr. Robert Vigfusson, Chief of the Trade and Quantitative Studies Section in International Finance at the Board of Governors of the Federal Reserve System, also took part as a discussant; and (5) Dr. Robert Webb, Professor of Finance at the University of Virginia, additionally engaged in the workshop as a discussant.

Of note is that Dr. Jian Yang, the J.P. Morgan Endowed Research Chair at the University of Colorado Denver Business School, presented at last year's EIA workshop on the impact of crude oil inventory announcements on prices using evidence from derivatives markets. Dr. Yang is also the JPMCC's Research Director and Professor of Finance and Risk Management.

Commodity Trading Strategies, Common Mistakes, and Catastrophic Blowups

Ms. Hilary Till presenting at a 2016 New York Society of Security Analysts' event, which provided a "Global View on Commodity Markets." To Ms. Till's left is Mr. Jonathan Goldberg, Founder & Chief Investment Officer of BBL Commodities, L.P.

Hilary Till, Joseph Eagleeye, and Richard Heckinger contributed a chapter on "Commodity Trading Strategies, Common Mistakes, and Catastrophic

Blowups." Joseph Eagleeye and Richard Heckinger are both members of the *GCARD*'s Editorial Advisory Board. Their chapter appears in the 2018 book, *Commodities: Markets, Performance, and Strategies*, Oxford University Press, New York. The book is edited by H. Kent Baker, American University; Greg Filbeck, Penn State Erie, the Behrend College; and by Jeffrey Harris, American University.

Financial Innovation and Technology Firms: A Smart New World with Machines

Dr. Kevin Chen, Ph.D., presenting on "Supply Side Economic Reform in China and Global Commodities Dynamics" during the August 2017 international commodity symposium at the University of Colorado Denver Business School's J.P. Morgan Center for Commodities (JPMCC). To Dr. Chen's left is Ms. Jodie Gunzberg, CFA, Managing Director and Head of U.S. Equities at S&P Dow Jones Indices and Member of the *GCARD*'s Editorial Advisory Board.

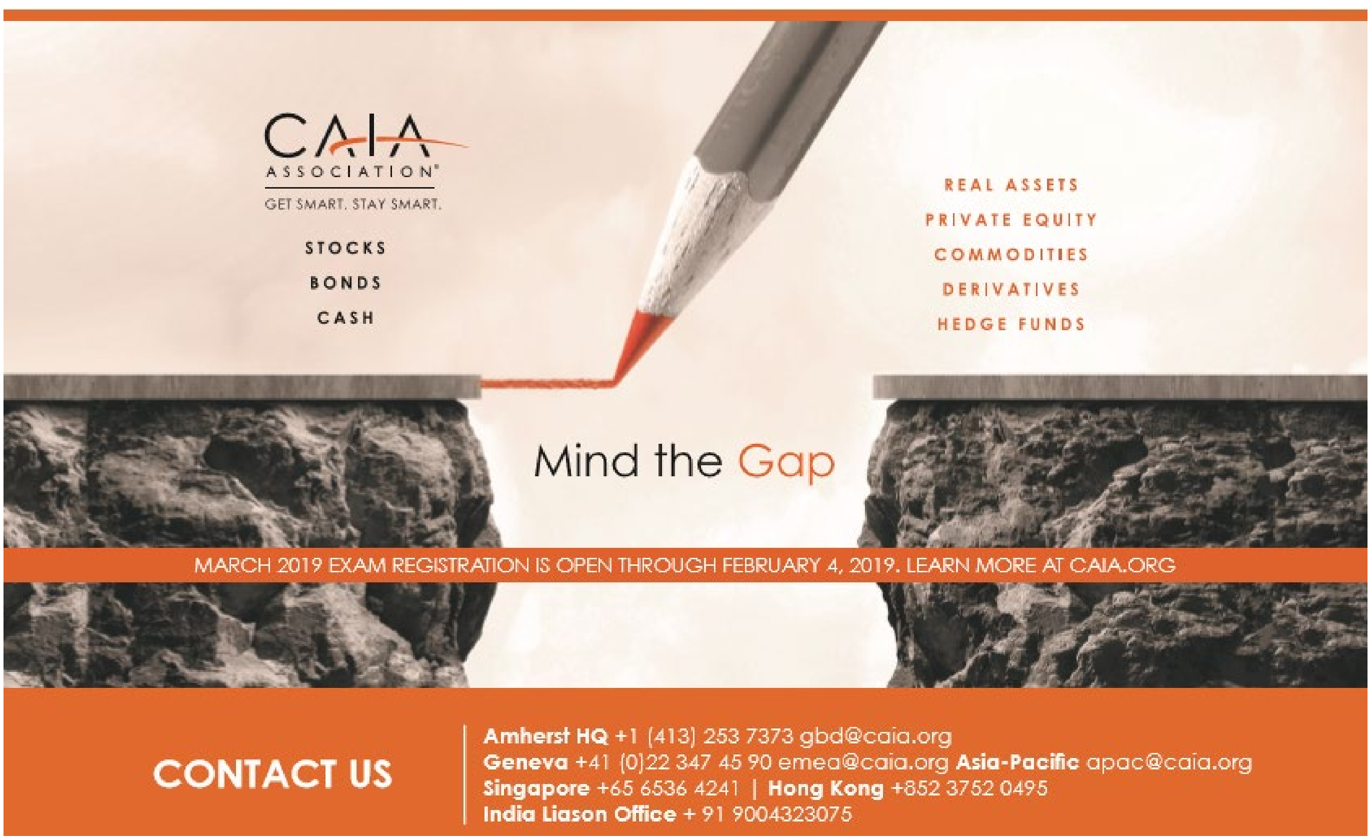
Dr. Kevin Chen, Chief Economist for Horizon Financial and Member of the *GCARD*'s Editorial Advisory Board, recently contributed a chapter on "Financial Innovation and Technology Firms: A Smart New World with Machines." The chapter will appear in the forthcoming book, *Banking and Finance Issues in Emerging Markets*, Vol. 25, Emerald Publishing Limited, London. The book is edited by William Barnett, University of Kansas and Center for Financial Stability; and by Bruno Sergi, Harvard University and University of Messina, Italy.

China: Credit, Collateral, and Commodity Prices

Dr. Keith Black, Ph.D., CFA, CAIA, discussed his *GCARD* digest article on "China: Credit, Collateral, and Commodity Prices," during his presentation at the JPMCC's August 2017 international commodities symposium.

Dr. Keith Black, Ph.D., CFA, CAIA, Managing Director, Curriculum and Exams at the Chartered Alternative Investment Analyst (CAIA) Association and Member of the *GCARD*'s Editorial Advisory Board, was featured in "Alternative Investment News for CAIA Members" for his *GCARD* digest article on credit, collateral, and commodity prices in China.

The Chartered Alternative Investment Analyst (CAIA) Association, a non-profit organization founded in 2002, is the world leader in alternative investment education. The CAIA Association is best known for the CAIA Charter®, an internationally recognized credential granted upon successful completion of a rigorous two-level exam series, combined with relevant work experience. Earning the CAIA Charter is the gateway to becoming a member of the CAIA Association, a global network of almost 10,000 alternative investment leaders located in 95+ countries, who have demonstrated a deep and thorough understanding of alternative investing. CAIA also offers the Fundamentals of Alternative Investments certificate program, an online course that provides an introduction to the core concepts of alternative investing. Having grown rapidly, the CAIA Association now supports vibrant chapters for its Charter Holder members located in financial centers around the world, produces world class research publications, and sponsors educational and networking events to help the CAIA community keep pace with the industry. CAIA is considered a leading authority and trusted voice for providing perspective on industry trends and developments worldwide. For more information, please visit CAIA.org.



Notes

Notes

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

GLOBAL COMMODITIES
APPLIED RESEARCH DIGEST

SPECIAL FEATURE: CRYPTOASSETS AND BLOCKCHAIN

Cryptocurrencies, Bitcoin and Blockchain: An Educational Piece on How They Work
Page SF1

How Futures Trading Changed Bitcoin Prices
Page SF36

Blockchain for Physical Commodity Markets - A Realist's Perspective
Page SF43

Interview with Don Wilson, CEO of DRW; and Co-Founder and Board Member, Digital Asset Holdings
Page SF48

Supported by a generous grant from

CME GROUP FOUNDATION

Business School
UNIVERSITY OF COLORADO DENVER

Cryptocurrencies, Bitcoin and Blockchain: An Educational Piece on How They Work

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

Michael Haigh, Ph.D.
Managing Director and Global Head of Commodities Research, Société Générale (U.S.)

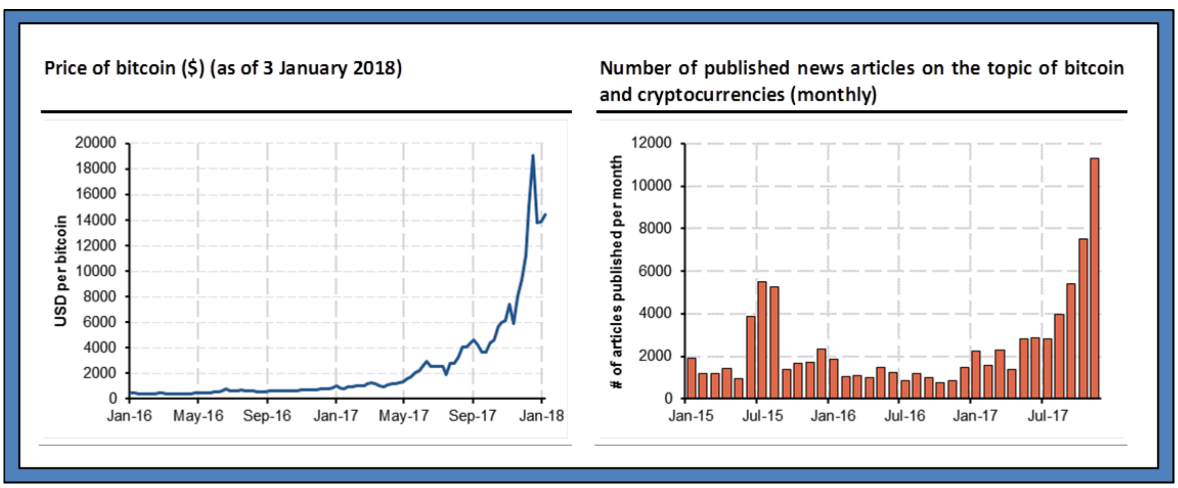
David Schenck
Commodities Analyst, Société Générale (U.K.)

Klaus Baader
Global Chief Economist, Société Générale (U.K.)

Introduction

The market and public curiosity for bitcoin and other cryptocurrencies has been undeniable. Every week, new cryptocurrencies, coins and tokens appear on online exchanges. The exchanges themselves have surpassed, in terms of users, some of the most established traditional stock-broker platforms. For example, it has been reported that Coinbase, a San Francisco-based cryptocurrency exchange, had amassed over 13 million users, some 3 million more than U.S. broker Charles Schwab. If anything, people are paying attention: the number of news articles on the topic of bitcoin and cryptocurrencies has risen substantially; please see Figure 1.

Figure 1



Sources: The Bloomberg, Cryptocompare, SG Cross Asset Research/Commodities.

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

Needless to say, the nascent sector has attracted a lot of skepticism and criticism. Last year Robert Shiller, a Nobel laureate, said "dabbling in bitcoin lies somewhere between gambling and investing" while former Fed chairman Alan Greenspan said bitcoin was "not a rational currency." Meanwhile, the vice-president of the European Commission, Valdis Dombrovskis, warned E.U. authorities of the "pricing bubble" in the growing cryptocurrency market, and amidst the ongoing chorus of critical comments from central bankers, several bank executives have said bitcoin resembles a scam. Since the significant move higher for most of last year, the digital currency has seen a severe correction.

The sector is still in its infancy and attempting to provide valuations, trade recommendations or any form of investment or trading advice in any capacity is not our objective in this article. Instead, we seek to address the many questions that investors and analysts ask about the nascent technology: what is a bitcoin? What is a blockchain? What problems do these solve? How do decentralized blockchains operate with no central organization? How secure is the blockchain? And what are the limitations embedded in the system? As such, this article is solely educational in nature.

To answer these questions, we structure this paper into three parts.

- In the first part, we briefly describe the nascent cryptocurrency market, focusing on the bitcoin system.

- In the second part, we examine bitcoin's price behavior from a quantitative perspective, highlighting the low correlation of bitcoin and other cryptocurrencies to other traditional asset classes.

- The final section provides a complete overview, including definitions and explanations of all the processes and mechanics behind bitcoin and the blockchain.

PART 1: CRYPTOCURRENCIES – THE NOISE AND THE SIGNAL

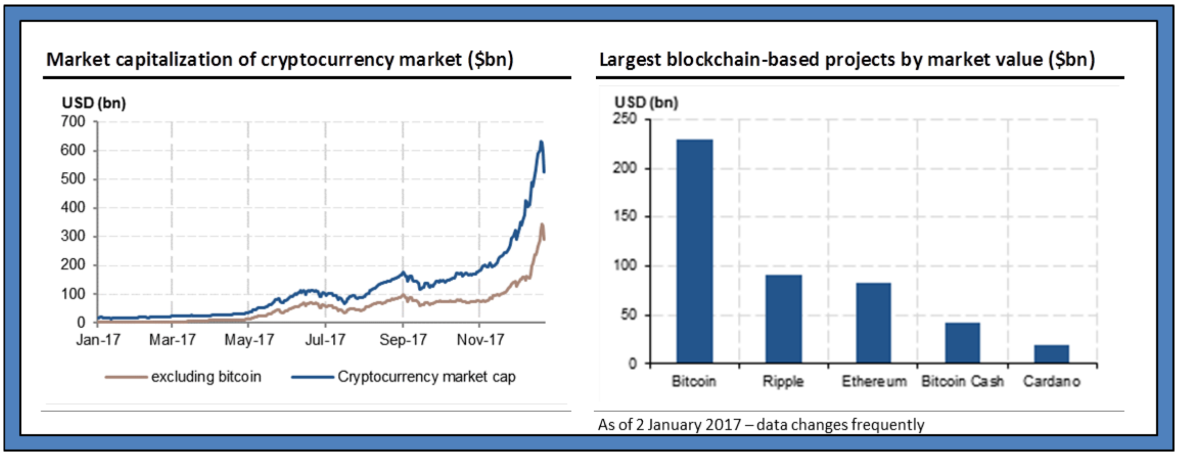
The rise (and fall) of bitcoin prices is reminiscent of previous bubbles: the tulip bubble of 1637 in terms of prices, and more recently, the internet bubble in the late 1990s. Evidence is growing that the cryptocurrency craze was spilling over to other asset classes. For example, when Long Island Iced Tea Corp. (LTEA US Equity) rebranded to Long Blockchain Corp. in late December 2017, investors flocked to buy the company's stock, driving a 200% price increase overnight.

The cryptocurrency market may be in a bubble and valuations may be out of control, but the technology known as blockchain, underlying bitcoin and other cryptocurrencies, is likely here to stay. In spite of the valuation excesses and noise, the aggregate market capitalization of the cryptocurrency market, having breached $700bn, suggests we may have already potentially sowed the seeds of a new asset class.

According to Coinmarketcap, dollar-valuations of the money supply (i.e., market cap) in the form of cryptocurrency rose 40-fold in 2017, rising from $15bn to $640bn. Bitcoin is perhaps the sector's most prominent example, but other coins are competing for dominance. (Please see Figure 2 on the next page.) Bitcoin's market share of the cryptocurrency market has already fallen below 40%, and over 1,350 blockchain-based projects already have exchange-traded tokens.[1]

Within the cryptocurrency sector, it is perhaps worthwhile to distinguish coins intended to replace traditional fiat currency from tokens, used in smart-contract blockchains and for which convertibility into fiat money is almost secondary.[2] Bitcoin and its spin-offs (such as Bitcoin Cash and Bitcoin Gold) have no other intended purpose than as a medium of exchange. In contrast, Ethereum coins (ETH) and its underlying blockchain, were designed to execute smart contracts, and the convertibility of these coins into fiat money (e.g., USD) is a secondary, albeit necessary condition for the operation and maintenance of the blockchain.

Figure 2



Sources: Coinmarketcap, SG Cross Asset Research/Commodities.

Unlike bitcoin, many blockchain-based projects are led by centralized organizations – often in the form of non-profit organizations (e.g., Ethereum Foundation), but also in the form of for-profit corporations (e.g., EOS's Block.one Corp.). According to Coinschedule, over 200 blockchain-based projects have successfully completed initial coin offerings (ICOs) in 2017, raising nearly $3.6bn from private investors. The proceeds of these ICOs are often earmarked for funding research and development in the underlying infrastructure (e.g., software development.) Among the notable 2017 ICOs, we recall Filecoin's ($257m) in August 2017, Tezos' controversial $232m as well as EOS' $185m fundraising.

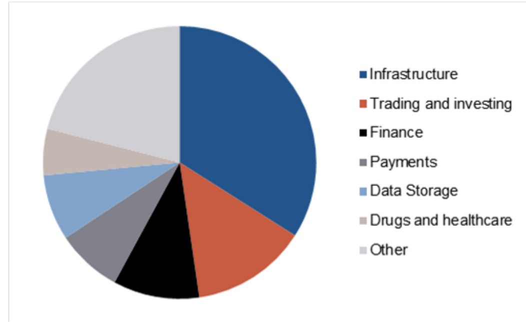
As shown in Figure 3 on the next page, many of these projects are based on payments and financial applications, but a sizeable fraction of the market is nevertheless focused on delivering infrastructure and data-storage solutions.

Figure 3

Ten largest 2017 initial coin offerings (ICO)

Company	Funds raised during ICO
Filecoin	$ 257 000 000
Tezos	$ 232 319 985
EOS Stage 1	$ 185 000 000
Paragon	$ 183 157 275
Bancor	$ 153 000 000
Kin Kik	$ 97 041 936
Status	$ 90 000 000
TenX	$ 64 000 000
MobileGO	$ 53 069 235
KyberNetwork	$ 48 000 000

2017 ICOs by category (weighted by funds raised)



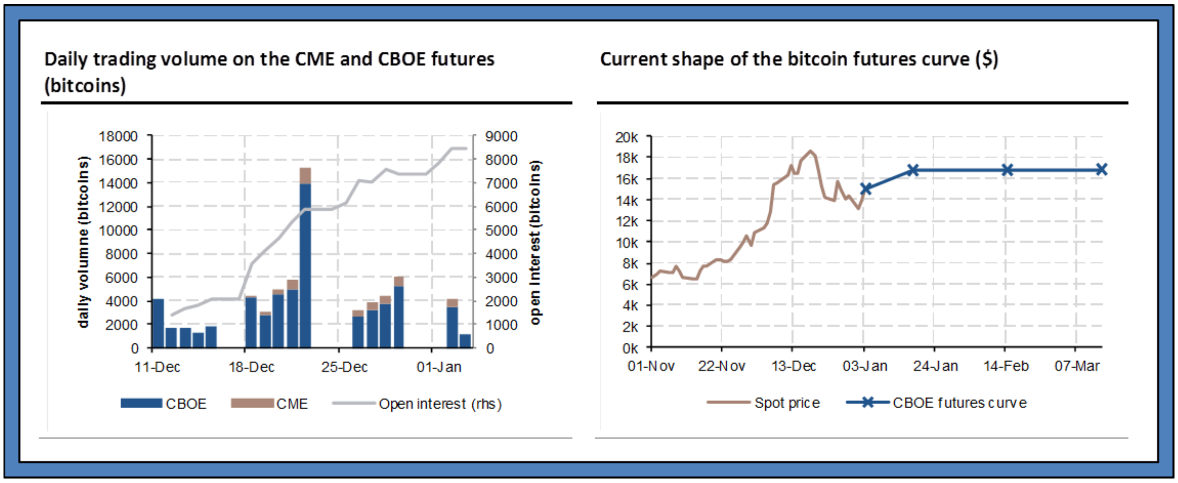
Sources: SG Cross Asset Research/Commodities, Coinschedule.com.

The Proliferation of Bitcoin Related Products

In practice, participation in ICOs is still limited to venture capitalists and retail investors lured by short-term returns, but cryptocurrencies look likely to find ways to encroach into traditional finance in the near term. The low interest-rate environment has also perhaps boosted the growth of the sector, increasing the relative appeal of alternatives to traditional money and, as long as we are in a very low rate world, the fashion for cryptocurrencies and tokens could continue. Bitcoin still trades very much on the fringe of mainstream finance, but it has a foot in the door. Some players have already seized the opportunity: assets under management with the Bitcoin Investment Trust ETF (GBTC US Equity) have, for example, grown to above $2bn, up from $160m a year earlier, and the CME and CBOE have launched cash-settled futures on bitcoin.

At the end of 2017, the volumes on both these exchanges started out relatively light; please see Figure 4 on the next page.

Figure 4



Sources: Bloomberg, SG Cross Asset Research/Commodities.

On CBOE futures, the reportable position level is set at five contracts, equivalent to a long or short futures exposure of five bitcoins. Traders holding positions in excess of this limit must currently disclose their positions to the Commodity Futures Trading Commission (CFTC), which then reports the aggregate position on a weekly basis in their weekly Commitments of Traders (COT) report. The table on the left-hand side of Figure 5 on the next page reports the data as of December 26, 2017. At the time, there were no commercial traders involved in the futures market. 34 non-commercial traders (i.e., large speculators) were net short of 1,801 contracts. By construction, small traders held the remaining long open interest.

The data were too thin to identify trends and characterize market structure, but we found the initial breakdown intuitive: the futures markets served primarily as a venue for shorting the cryptocurrency. Longer term, commercial traders could appear in the form of bitcoin miners, who validate transactions on the network, and look to hedge their fiat-denominated costs (e.g., electricity, hardware) with bitcoin revenues.

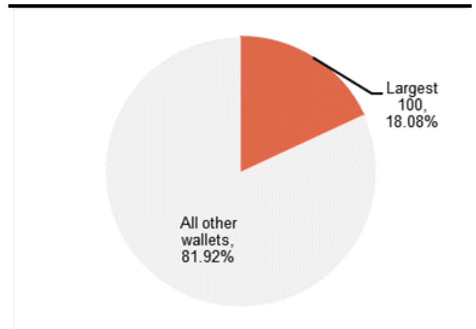
Perhaps a more telling (and daunting view) of the bitcoin market involves looking at the holding concentration of the largest wallets (akin to accounts.) Since all bitcoin transactions are public, it is possible to compute the balance of each wallet on the network. According to Bitinfocharts, the largest 100 wallets hold approximately 18% of all bitcoins. (Please see the pie-slice chart on the right-hand side of Figure 5 on the next page.) It also estimates that there are at least 2,442 wallets holding bitcoins worth more than $10m each. On the one hand, this figure may overstate concentration, as some of these wallets are exchange vaults holding client deposits. On the other hand, this breakdown may underestimate concentration, as anyone on the network can create as many wallets as he or she wishes.

Figure 5

CFTC Commitment of Traders report on CBOE bitcoin futures, week of 26 December

Non-commercial	
Long	1232
Short	3033
Spreading	117
Net position	*-1801*
Non-reportables	
Long	2388
Short	587
Net position	*1801*
Total	
Open interest	*3737*

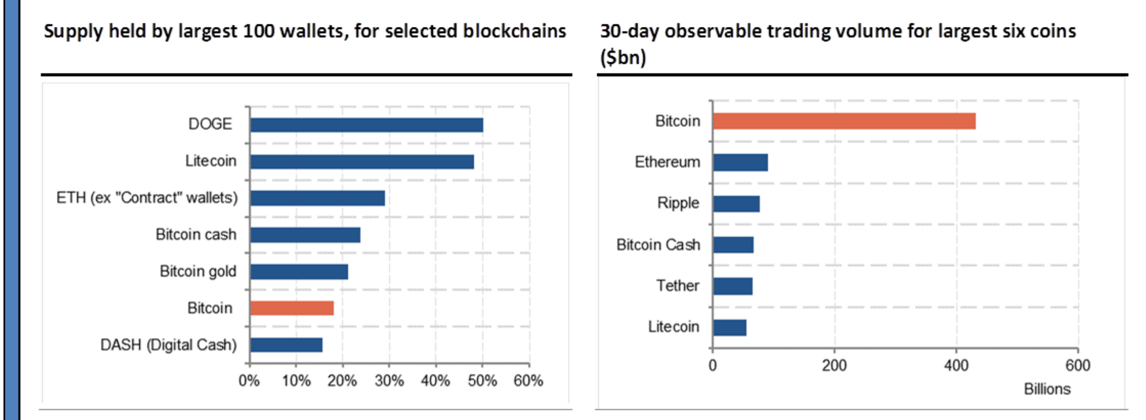
Largest 100 wallets hold 18% of all bitcoins



Sources: SG Cross Asset Research/Commodities, CFTC, Bitinfocharts.

On other blockchains, concentration is equally problematic: according to Etherscan, the largest 100 Ethereum wallets (excluding "Contract" wallets, which are "smart contract" accounts not held by individual holders) currently hold 29% of all issued coins. On the Litecoin blockchain, the largest 100 wallets control over 48% of the coin supply; please see the bar chart on the left-hand side of Figure 6. And on the DASH blockchain, the largest 100 wallets concentrate 16% of the circulating supply. Again, these figures may overestimate concentration since some wallets may refer to exchange vaults aggregating client deposits, but clients can conversely create many wallets at no additional cost.

Figure 6



Source: SG Cross Asset Research/Commodities.

In terms of exchange trading volume, bitcoin has dominated the cryptocurrency space, as shown in the bar chart on the right-hand side of Figure 6.

Defining Cryptocurrencies

Are cryptocurrencies, like bitcoin – and as their name suggests – actual currencies? Or should we treat them as commodities? Considering the basic definition of money (unit of account, means of transaction, store of value), it is understandable why the jury is still very much out on the subject, and we currently see the nascent sector having many features like commodities. Like gold, the value of bitcoin is primarily socially determined. Both gold and bitcoins are divisible and fungible. While the supply of gold is assumed to be finite, the maximum supply of bitcoin is set at 21 million. As no government (currently) recognizes bitcoin or other cryptocurrencies as legal tender, it therefore perhaps makes more sense for bitcoin to be classified as a commodity rather than as a fiat currency.

The question is not purely academic either, as the way national governments and regulators decide to treat cryptocurrencies will determine and shape how/whether the sector develops and evolves.

- The CFTC said it considered tokens issued through initial coin offerings to behave as commodities. In a September 2017 ruling against a San Francisco-based start-up, the CFTC decided that bitcoin and other digital cryptocurrencies were covered by the Commodity Exchange Act (CEA).

- The Securities Exchange Committee (SEC) has already stopped several ICOs, in effect ruling that cryptocurrencies and digital tokens fell within its mandate. The SEC has also refused to approve several cryptocurrency-based ETFs, and warned investors against scams.

- The U.S. Internal Revenue Services (IRS) says bitcoin must be treated as intangible property. Capital gains and losses must be reported for tax purposes.

- The U.S. Treasury has said "virtual currency does not have legal tender status in any jurisdiction."

Outside of the U.S., official organizations have also issued rulings. For example:

- In China, financial institutions are banned from accepting, using or selling virtual currencies. Exchanges must register with the government.

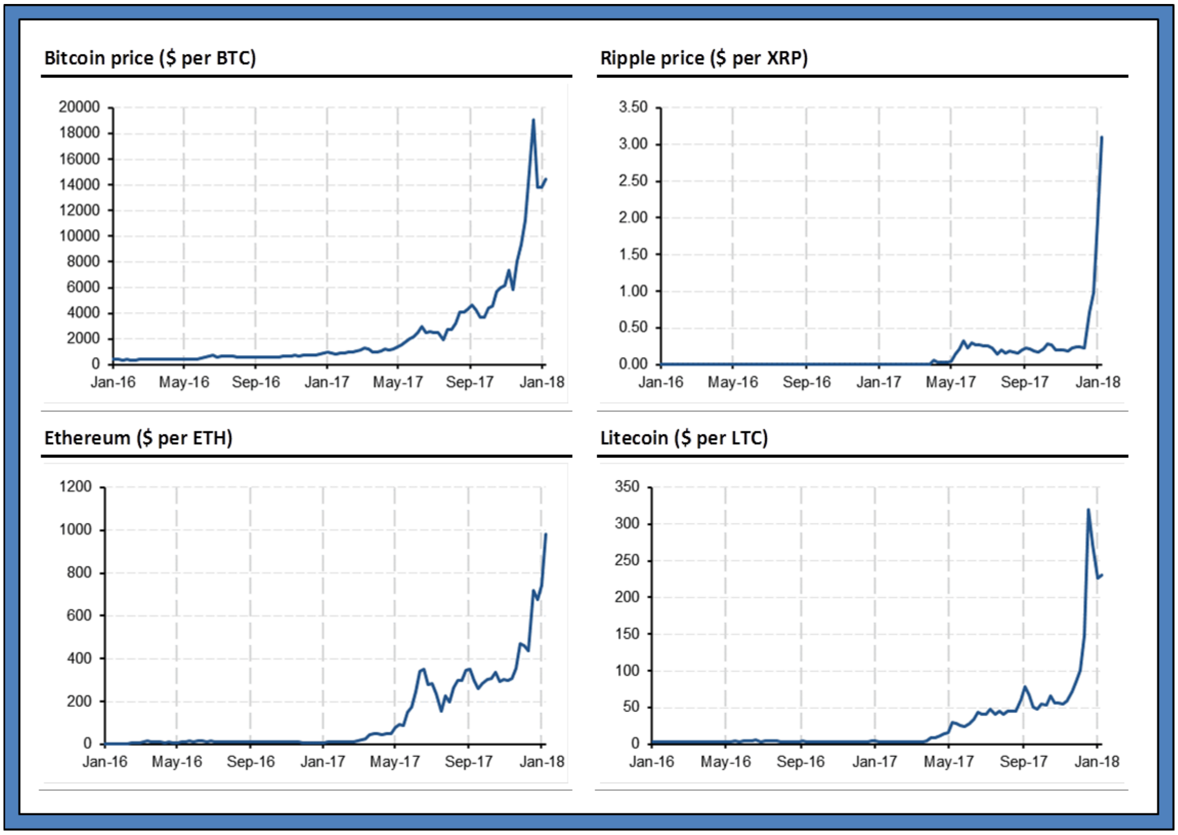
- In a ruling against one of its member states, the European Central Bank has banned E.U. members from introducing government-backed digital currencies.

- In Egypt, the Grand Mufti has issued a fatwa (religious ruling) against the use of bitcoin.

PART 2: FINANCIAL SPECS OF CRYPTOCURRENCIES AND RETURN VERTIGO

The return on cryptocurrencies had been spectacular, if not surreal, as illustrated in Figure 7 on the next page.

Figure 7

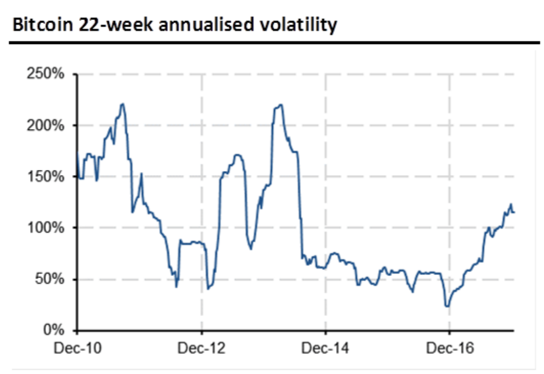


Sources: CryptoCompare, SG Cross Asset Research/Commodities.

Extreme Volatility

For instruments intended to replace fiat currency, bitcoin and other cryptocurrencies have scored poorly on the "store of value" criteria, given their bouts of extreme volatility. Figure 8 on the next page illustrates bitcoin's past high volatility and maximum drawdown figures while Figure 9, also on the next page, shows how highly skewed bitcoin's returns have been along with the scale of its past large weekly losses.

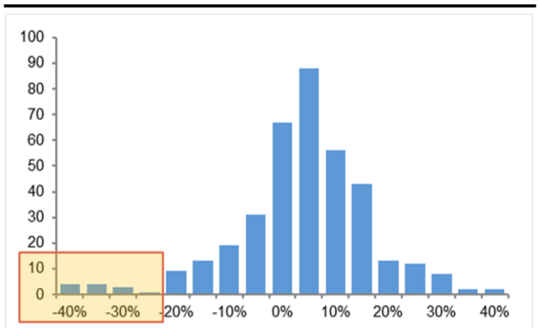
Figure 8



Source: SG Cross Asset Research/Commodities.

Figure 9

Distribution of weekly bitcoin price returns shows high skew



Buckle-up! Eight largest weekly losses since 2016

week of: 17 Sep 17	-14.04%
week of: 17 Jan 16	-15.41%
week of: 18 Jun 17	-15.77%
week of: 19 Mar 17	-18.07%
week of: 26 Jun 16	-19.63%
week of: 12 Nov 17	-22.88%
week of: 16 Jul 17	-27.16%
week of: 24 Dec 17	**-32.40%**

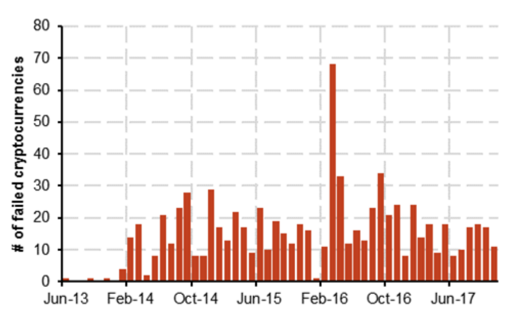
Source: SG Cross Asset Research/Commodities.

Survival Bias

Besides the past high levels of volatility, the survival rate of cryptocurrencies is rather low. Using data provided by Coinmarketcap going back to April 2013, we found more than 860 defunct cryptocurrencies, representing 40% of the observable universe of cryptocurrencies; please see Figure 10 on the next page. Furthermore, it is not unlikely that many more cryptocurrencies failed to launch after their initial coin offering – suggesting that these statistics are probably conservative. As of the writing of this article, the average lifetime of defunct cryptocurrencies stands at 327 days, compared with 513 days for surviving cryptocurrencies. There was a notable surge of cryptocurrency extinctions in March 2016, when the price of bitcoin fell by over 25%.

Figure 10

40% of cryptocurrencies failed between 2013 and 2017



Missing in action: largest suspected failed cryptocurrencies

Symbol	First seen	Last seen	Peak market cap	Days
ROUND	27/11/16	10/01/17	193m USD	44
DAO	22/05/16	18/12/16	160m USD	210
APH	23/03/14	25/05/14	70m USD	63
SPA	16/03/14	01/03/16	38m USD	716
DRACO	07/03/16	11/05/17	28m USD	430
PTS	24/11/13	09/04/16	25m USD	867
MUSE	05/10/15	08/06/17	20m USD	612

Source: SG Cross Asset Research/Commodities.

The above right-hand table of Figure 10 further shows the largest seven suspected failed cryptocurrencies. At their price peak, the dollar value of the circulating supply was worth tens and in some cases hundreds of million dollars. ROUND and DAO coins were worth, in aggregate, $193m and $160m at their market peak. Going forward, it is likely that the high rate of failure will persist, or perhaps even increase as more new products appear.

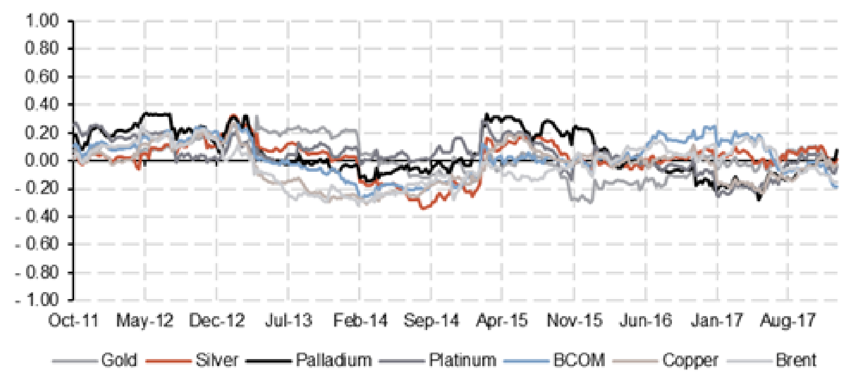
Correlation Profiles

We computed the correlation of bitcoin weekly returns against the return of several financial instruments across several asset classes, and not surprisingly found they are unrelated, as the price behavior of bitcoin has been entirely speculative. For the period from July 2010 to January 2018, the weekly return correlation of bitcoin with commodities hovered near zero; please see Figure 11 on the next page.

Figure 11

Rolling 52-week correlation of bitcoin versus other selected commodities

Average	Gold (spot)	Silver (spot)	Palladium (spot)	Platinum (spot)	BCOM	Copper (GSCI)	Brent (GSCI)
Bitcoin	0.02	0.02	0.06	0.04	0.02	(0.04)	(0.03)



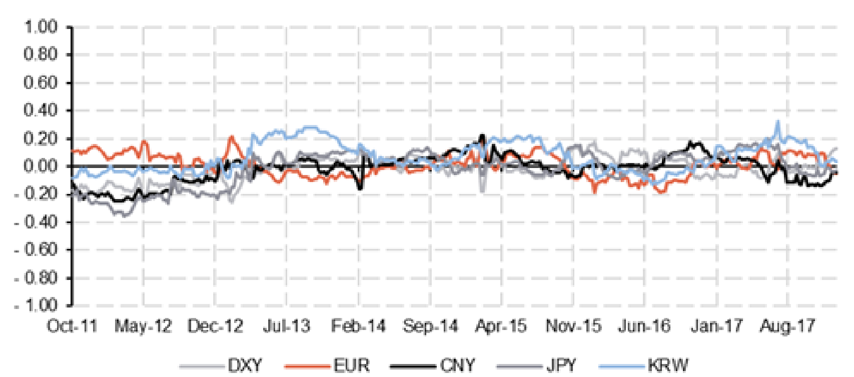
Source: SG Cross Asset Research/Commodities.

Likewise, correlations with selected fiat currencies revealed no relationship, as shown in Figure 12.

Figure 12

Weekly correlation of bitcoin versus selected currencies

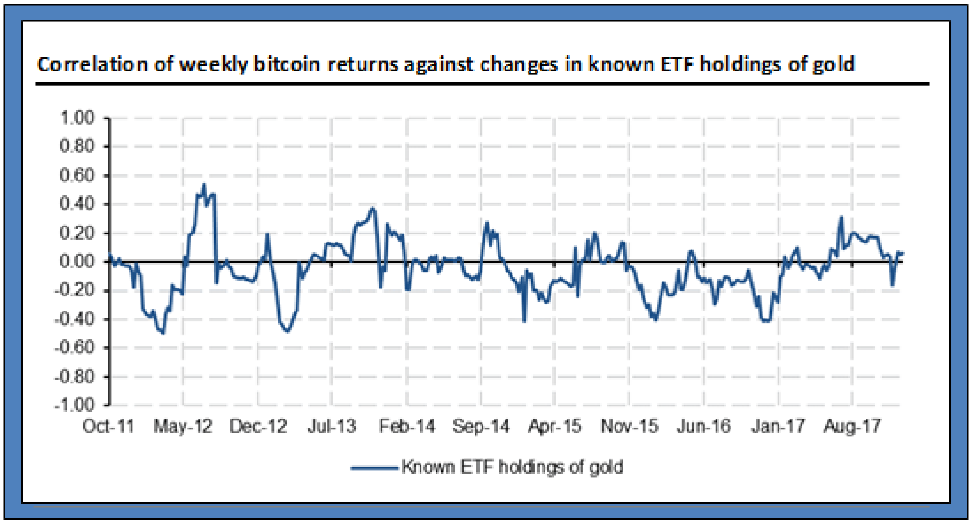
	DXY	EUR	CNY	JPY	KRW
Bitcoin	(0.03)	0.01	(0.02)	(0.02)	0.01



Source: SG Cross Asset Research/Commodities.

We computed the rolling six-month correlation between weekly bitcoin returns and changes in known ETF holdings of gold (ETFGTOTL Index) to assess whether there might be a relationship between flows into gold ETFs and bitcoin prices. Here also, we found little relationship, as seen in Figure 13.

Figure 13



Source: SG Cross Asset Research/Commodities.

Finally, we also computed the cross-correlation of weekly returns between some of the largest or most established cryptocurrencies, as shown in Figure 14. Interestingly, we found that cryptocurrencies themselves exhibit low levels of cross-correlation. This underscores the extreme level of speculation and the absence of any meaningful structure, relationship or cohesion amongst the cryptocurrencies in our analysis. The highest recorded level of correlation was found to be with Litecoin (LTC), at 0.40.

Figure 14

Weekly return correlations

	ETC	XMR	MIOTA	XLM	LTC	XEM	DASH	ETH	BCH	XRP	BTC
ETC	1.00	0.05	0.01	0.06	0.09	0.06	0.03	0.10	-0.01	0.02	0.05
XMR		1.00	0.06	0.08	0.14	0.12	0.11	0.10	0.03	0.01	0.14
MIOTA			1.00	0.17	0.05	0.09	0.09	0.10	0.06	0.00	0.14
XLM				1.00	0.13	0.19	0.11	0.08	0.00	0.31	0.10
LTC					1.00	0.20	0.11	0.07	0.03	0.18	0.40
XEM						1.00	0.05	0.14	0.03	0.11	0.11
DASH							1.00	0.10	0.07	0.00	0.17
ETH								1.00	-0.01	0.05	0.11
BCH									1.00	-0.01	0.00
XRP										1.00	0.14
BTC											1.00

Source: SG Cross Asset Research/Commodities.

PART 3: UNTANGLING BITCOIN AND THE BLOCKCHAINS

Cryptocurrencies as a concept is still relatively new, and investors are keen to understand the new technology to assess potential value, if any. In this section, we therefore define bitcoin and its underlying blockchain. To shed light on some of the system's trickiest details, we provide a rudimentary overview of the cryptographic principles underlying blockchains.

What is Bitcoin?

A bitcoin simultaneously refers to a unit of account as well as a decentralized system of payment. In its foundational paper, published in 2007, Satoshi Nakamoto, its pseudonymous author, described the system as a pure "peer-to-peer version of electronic cash," allowing participants to transfer online payments directly from one to another without the need for a centralized financial institution.

Multiple projects have attempted to create a decentralized virtual currency as early as the 1990s. However, the first practical implementation of bitcoin only appeared in 2009 with the release of the bitcoin software. Bitcoin's first transaction (the genesis block) contains, as a comment in its metadata, "The Times 03/Jan/2009 Chancellor on brink of second bailout for banks", a reference to the headline of the front-page of the British newspaper, *The Times*, published early in 2009. The first recorded bitcoin-based transaction famously dates to May 2010 when a Florida-based user of the online bitcointalk.org forum successfully traded 10,000 bitcoins with another user in exchange for two pizzas at a local vendor.

Since then, bitcoin has evolved and grown to become the world's largest digital currency by market capitalization. As we noted in the first section, bitcoin related products have started to emerge (ETFs and futures), crossing into more mainstream financial channels, but despite this, its extreme volatility and the numerous questions on its innate viability combined with uncertainty surrounding its longevity remain considerable.

One particular feature of bitcoin is its limited supply, capped at 21 million units. Each bitcoin is also divisible into 1 million individual parts commonly known as *satochis* in reference to the anonymous author of the original paper.

What Problem Does Bitcoin Intend to Solve?

As described by its author, bitcoin intends to become "peer-to-peer electronic cash." It aims to allow the online ("electronic") transfer of value from one participant to another ("peer-to-peer") without the need of a centralized organization such as a clearing house or a bank (instead relying on decentralized ledgers.)

In its foundation paper, Satoshi Nakamoto explained that "commerce on the internet has come to rely exclusively on financial institutions serving as trusted third parties to process electronic payments." According to the author, this system, based on "trust," has "inherent weaknesses" in the form of high transaction costs, fraud, and mediation. Importantly, and unlike physical currency, online transactions are "reversible" and "merchants must be wary of their customers, hassling them for more information than they would otherwise need."

As it currently stands, electronic commerce indeed relies heavily on centralized organizations such as PayPal, VISA, MasterCard and banks to enforce and secure online payments and transfers. In exchange for the trust they provide, these organizations charge a processing fee, often in excess of 1% of the value. Businesses providing remittances services (e.g., Western Union) similarly charge significant fees to transfer value from one part of the planet to another.

Bitcoin intends to substitute the trust-based model involving intermediaries with a payments system based on cryptographic proof, "allowing two willing parties to transact directly with each other without the need for a trusted third party."

Where is the Money?

Bitcoin, like other currencies (e.g., the euro, U.S. dollar) has no intrinsic value other than the social value we agree on. We accept to make transactions in bitcoins just the way we accept to make transactions in U.S. dollars – with the assumption that we can later use the proceeds to make further purchases and believing that others will do the same.

A bitcoin wallet address (text and QR-code)

`1GQQ5BaGJ5CeTYaihNWCcHbWUht4bBy5oC`

Source: SG Research/Commodities

However, unlike hard currency or even intangible commodities like electricity, a bitcoin has no physical form besides a seemingly-random string of characters recorded on the system. Moreover, this string of characters is publicly visible to all participants in the bitcoin network, and its source is also perfectly traceable.

Ownership, therefore, takes the form of a social construct and is distinct from physical possession. To understand bitcoin, it is best to compare it with intellectual property: bitcoin ownership exists much the way patents and copyrights only exist within the legal framework in which these were designed and granted. Neither bitcoin nor patents have physical substance besides the written social contract in their respective systems.

Each bitcoin in circulation is, at any time, associated with an address, as shown in the image above. An address is a string of characters and uniquely identifies a bitcoin wallet, much the way an IBAN (international bank account number) uniquely defines a bank account number. Each wallet also has a password-like secret key. Anyone in possession of the secret key can use the wallet and move funds out.

How are Bitcoins Acquired?

To acquire bitcoins, one needs to find another participant willing to sell. To improve liquidity, buyers and sellers often meet on digital exchanges, but one could just as well find someone on the street and exchange directly with him provided a mutually-agreed price can be found. The seller needs to send the bitcoins to your public address in exchange for which you provide dollars, euros, goods or services.

The Issue of Trust

To keep track of each user's balance, the bitcoin system keeps a history of transactions, known as the blockchain. The blockchain is a file containing the history of all transactions on the bitcoin network. Unlike hard currencies like the U.S. dollar, bitcoin and other cryptocurrencies operate without a central organization such as a commercial bank, a clearing house, a central bank or a government. Instead, the source of truth and ultimately people's faith in the currency lies with the blockchain itself, which is distributed and decentralized among the network participants. Distribution refers to the idea that many participants simultaneously own parallel copies of the blockchain while decentralization refers to the notion that changes to the blockchain are ultimately decided by the majority of participants through a process known as consensus.

To claim ownership over a bitcoin, one has to demonstrate having received the bitcoin in a previous transaction – and the blockchain (or history of transactions) serves as the "paper trace" of these transactions. As such, ownership is enforced not by any single party or judge, but rather by consensus among the participants on the bitcoin network, all of whom simultaneously maintain a copy of the ledger.

Figure 15

Block #	Timestamp	Transactions	Recorded by	Size
502343	Jan 3, 2018 10:28:30 AM	2472		983392
502342	Jan 3, 2018 10:21:01 AM	2348		962408
502341	Jan 3, 2018 10:17:41 AM	1913	AntMiner	979423
502340	Jan 3, 2018 9:23:08 AM	2684	AntMiner	948962
502339	Jan 3, 2018 9:21:13 AM	2553	AntMiner	973348
502338	Jan 3, 2018 9:17:57 AM	2571	AntMiner	978949
502337	Jan 3, 2018 9:08:27 AM	2796	AntMiner	972043
502336	Jan 3, 2018 8:54:17 AM	2644		968652

Sources: SG Cross Asset Research/Commodities, Blockexplorer.com.

For efficiency purposes, the bitcoin blockchain records transactions in groups called blocks. The above table in Figure 15 shows the most recent eight blocks recorded on the blockchain during one timeframe. The most recent block (block #502343) was recorded on 3 January 2018 at 10:28am and contained 2,472 individual transactions. One of these transactions is shown in Figure 16 on the next page and involves the transfer of 0.076 bitcoins from one address to another.

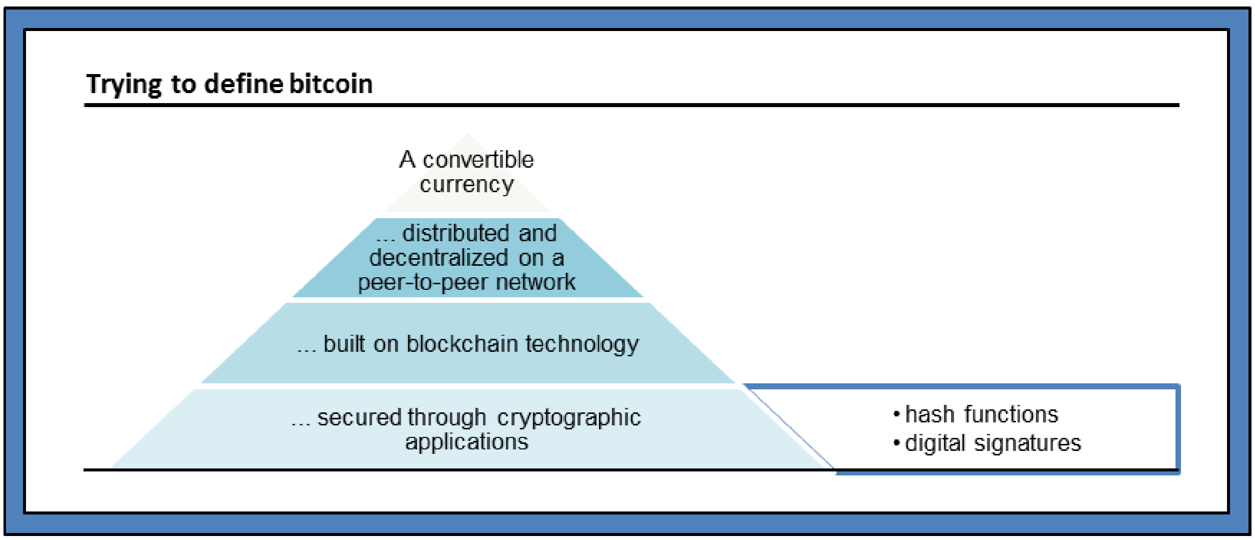
Figure 16

Sources: SG Cross Asset Research/Commodities, Blockexplorer.com.

The Bitcoin Invisible Hand

The decentralized nature of bitcoin is a key feature of the system, and understanding how the blockchain operates with no centralized organization is fundamental in any attempt to understand the digital currency. We illustrate bitcoin's fundamental design in Figure 17.

Figure 17



Source: SG Cross Asset Research/Commodities.

At the lowest level, bitcoin is based on a few cryptographic concepts such as hash functions and digital signatures. These jointly provide security and authentication. As explained above, transactions are recorded in a file-like ledger known as the blockchain. Unlike traditional ledgers, blockchains are immutable, meaning that past transactions can neither be altered nor reversed. The blockchain itself is distributed and decentralized on the bitcoin peer-to-peer network such that no single party controls the blockchain. Faith in the currency's security and decentralization then allows the virtual currency to achieve convertibility into other fiat currencies. We review each of these layers in turn.

Layer 1: Cryptographic Foundation

At its core, the existence of bitcoin and other blockchains is predicated on a set of cryptographic concepts, which allow these systems to operate in decentralized but nevertheless coordinated manners. While these concepts are mathematically very complex, a principle understanding of these concepts allows for a better understanding of the way blockchains ultimately achieve what they are designed to do – namely, maintaining an immutable ledger of transactions.

We therefore begin by introducing hash functions, one of the protocol's basic building bricks, the understanding of which will allow us to then better comprehend hash puzzles and bitcoin mining. We also briefly introduce digital signatures that underpin authentication and authorization in blockchains.

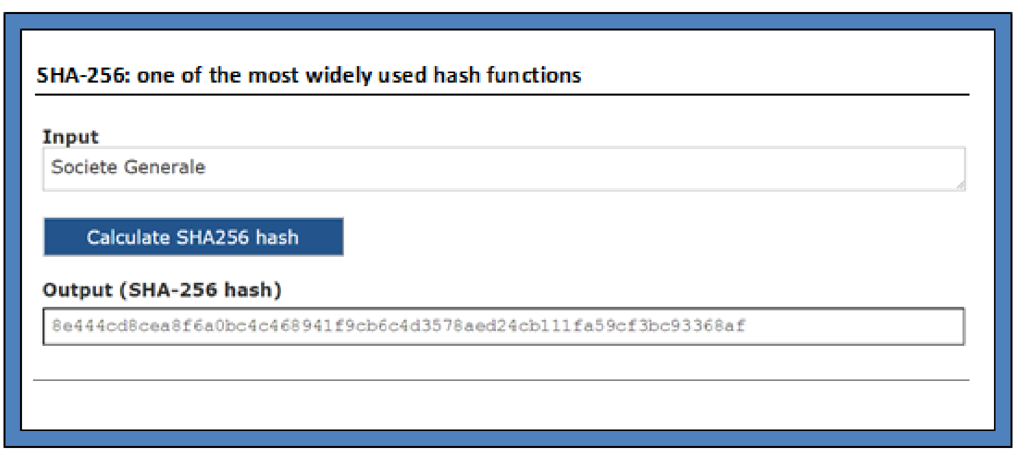
Hash Functions

Blockchains rely heavily on cryptographic algorithms known as hash functions. In computer science, a function is a set of computer instructions (an algorithm) designed to convert an input (e.g., a number, a sequence of characters) into an output.

Hash functions are a group of functions designed to accept a sequence of characters of any length and convert that input into a fixed-length sequence of characters. We say a hash function converts an input into its hashed representation. This representation is known as the hash digest, or just hash.

The most widely-used hash function is known as **SHA-256**, which was designed and open-sourced by the U.S. National Security Agency (NSA) in the early 2000s. This particular hash function maps an arbitrary input to a sequence of 64 characters (encoded by 256 bits.) Although the hash function creates a seemingly random output, the output is nevertheless consistent every time it is performed on the same input. By way of illustration, the hash representation of "Societe Generale" (the input) using the SHA-256 algorithm is represented in Figure 18. As expected, the digest has fixed-length (64 characters.)

Figure 18



Source: SG Cross Asset Research/Commodities.

There are many hash functions, but for these functions to be useful in cryptographic applications, these must have a number of desirable features. Specifically, hash functions must be computationally efficient, minimize collisions, conceal the input message, and must be puzzle-friendly. We briefly explain what each of these features mean:

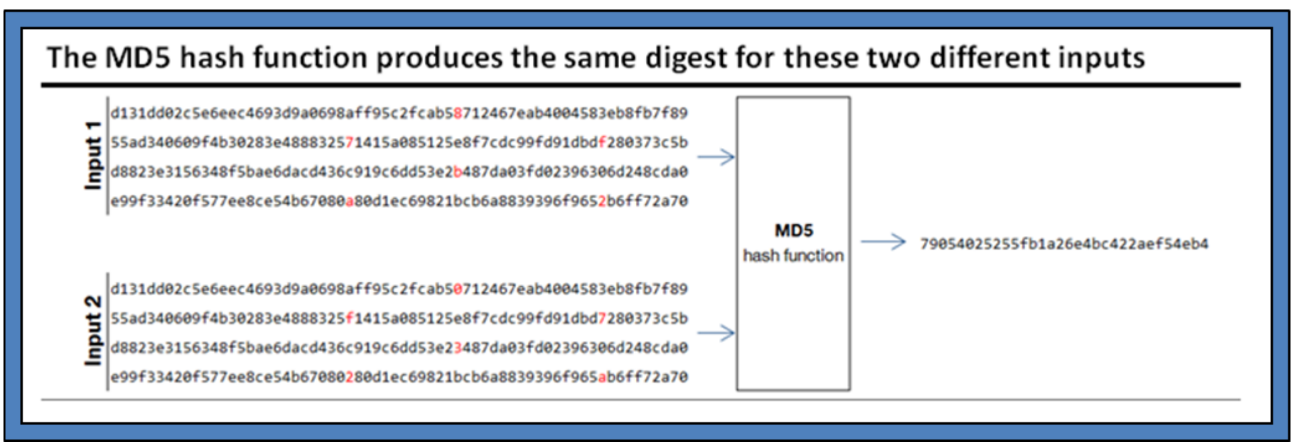
1. Firstly, hash functions should be computationally efficient – meaning that the computation of the hash function for a given input must be technically feasible with the average available hardware. Currently, the average computer or telephone can compute several hundred thousand SHA-256 functions per second – making this algorithm computationally efficient.

2. Furthermore, hash functions should be collision-free. A collision arises when the digest (or hashed representation) of two different inputs are the same.

   Collisions should theoretically be inherent to hash functions since the universe of possible inputs is significantly larger than the universe of possible outputs. We recall that the input to a hash function can be of any size while the output of the hash function has fixed-length. For example, the SHA-256 algorithm always yields 64-character outputs. There is therefore a limited universe of possible outputs, specifically 2^{256} possible outputs – please see the side box on the next page. The number of inputs is, on the other hand, however infinite, implying that collisions are inherent to hash functions.

   For example, MD5, another widely-used hash function was "broken" in 2005 when researchers from Shandong University in China described how two different sequences (shown in Figure 19) produced the same hash (i.e., a collision) when passed to the MD5 hash function.

Figure 19



Sources: http://www.mathstat.dal.ca/~selinger/md5collision/, SG Cross Asset Research/Commodities.

Although no hash function can theoretically be collision-free, some hash functions are notably efficient at minimizing them. For example, the SHA-256 algorithm has, to date, not produced a collision. Stated differently, we have thus far been unable to find two different inputs which transform into the same digest when passed to the SHA-256 function.

As it stands, one could try 2^{130} different inputs through the SHA-256 hash function (an unreasonably large number), and then, the probability of finding a collision would still be below 100%.

Collision-free hash functions, like the SHA-256 algorithm, have a number of useful properties. Principally, if the hash function is known to be collision-free, then the digest uniquely represents or identifies the input – there is a (probabilistic) one-to-one mapping of input to output. Stated differently, the hash output is akin to a digital fingerprint of the input. If we see two identical hashes, then it is safe to assume that the inputs are the same. And, because hashes are often shorter than the inputs that they represent, hash functions succinctly and wholly summarize inputs.

3. Hash functions should obfuscate or conceal the original input. Given a digest, it must be difficult to find the original input without further knowledge of the possible universe of inputs – stated differently, it must be difficult to decipher the output of the hash function. Again, the SHA-256 function succeeds at this – there is indeed no easy way to see that underlying the hash 8e44[…]36af is the input "Societe Generale."

4. Hash functions must be puzzle-friendly: given a hash function (e.g., SHA-256) and a subset of outputs, there should be no better way to find an input that converts into one of the outputs than to try randomly. For example, given the SHA-256 algorithm, if we wanted to find an input whose digest started with a "0", there would be no better way than to try random inputs until we indeed found one.

   For example, if one wanted to find the lowest number whose SHA-256 hash started with five zeroes (e.g., "00000691457f…"), there would be no better way than to try numbers until one was found. This number is 596,138.

256-bits, 64 characters... ?

A **bit** is the most basic unit of information in computing, representing a `1` or a `0`.

Using 4 bits, we can create 16 different combinations e.g. `1-0-0-1`, `1-0-1-1`

If we assign each combination to a character (e.g. `1-0-0-1` to `A`), we can create a 16-character alphabet using 4 bits at a time.

Since 4 bits can map to one of 2^4 (=16) unique characters, 256 bits (i.e. 64 characters) can map to 2^{256} unique different outputs.

Source: SG Research/Commodities

Ensuring that hash functions are both collision-free and puzzle-friendly may seem like two faces of the same coin, but they ultimately achieve different objectives: the collision-free feature ensures the uniqueness of the input-output mapping: given two identical hashes, the probability that they were produced using the same input converges to 1 for collision-free hash functions. Puzzle-friendliness, on the other hand, ensures the randomness of the algorithm such that to produce a desired pattern, there is no smarter way than to try random inputs.

Digital Signature

Digital signatures are another common cryptographic application and a foundational concept underlying bitcoin and other blockchains. While the mathematical derivation of the concept is beyond the scope of this paper, understanding the mechanism is nevertheless vital for a thorough understanding of the blockchain.

Like a handwritten signature (such as in the right-hand box), a digital signature should fulfil two requirements:

1. Only the signee can append his signature to a document or message – he is the sole owner of the signature, and his signature commits the signee to the content of the message on which he appended his signature;

2. Anyone can verify the authenticity of the signed message by looking at the signature.

In practice, manuscript signatures are not impossible to counterfeit. Digital signatures improve on this and are nearly impossible to counterfeit, provided a number of conditions are fulfilled.

Digital signatures are often implemented using a public-private key algorithm, the most famous of which is known as RSA-encryption. In public-private key encryption, two related-but-different sequences of characters known as keys are first generated:

- The first is known as the public key, and, as the name suggests, can be distributed widely.

- The second key is known as the private or secret key. As the name suggests, the private key must be kept secret and acts as a password.

Importantly, only the public key can decrypt a message encrypted by the private key, and vice versa. Encryption refers to the process of concealing a message such that only the holder of the key can reveal the original message. This asymmetry effectively allows one party to sign a document and another party to authenticate the document. (Digital signatures are contrasted with hash functions in Box 1 on the next page.)

For instance, suppose that Mark wanted to send a signed message to Sophie (e.g., "Mark pays Sophie $20".) Mark could then encrypt the message using his private key, send the encrypted message as well as his public key to Sophie. Sophie, receiving these two elements, can then decrypt the message using Mark's public key. A valid decryption not only reveals the message, but simultaneously verifies that the message was indeed encrypted by Mark and is authentic. As a matter of fact, anyone (including Sophie) can verify the message's authenticity as the public key is … public.

Box 1

Summary: hash functions and digital signature

Hash functions and digital signatures are two key cryptographic concepts underlying blockchain technologies. Although related, hashing and signing are nevertheless different in their **reversibility**: the output of a hash function **cannot** be converted into its original input using a known function. Digital signatures on the other hand are a form of **encryption:** the encrypted output can be reconverted to its original form provided the correct key is provided.

Hashing	**Encryption (e.g. digital signatures)**
one-way	*two-way*
⟶	⟷

Public key encryption plays a central role in bitcoin and other blockchains. As a matter of fact, each account (known as a wallet) is in fact defined by a public key, known as the address. The only person able to move bitcoins out of a wallet is the person who knows the private key associated with the wallet's address. On the bitcoin network therefore, users can create new wallets at will, by creating new public-private key pairs. As a matter of fact, users are encouraged to generate multiple wallets to protect privacy, by distributing their holdings across several wallets; please see Figure 20.

Figure 20

You can generate wallets at will by creating public-private key pairs

Wallets can be created at
www.bitaddress.org

Source: SG Cross Asset Research/Commodities.

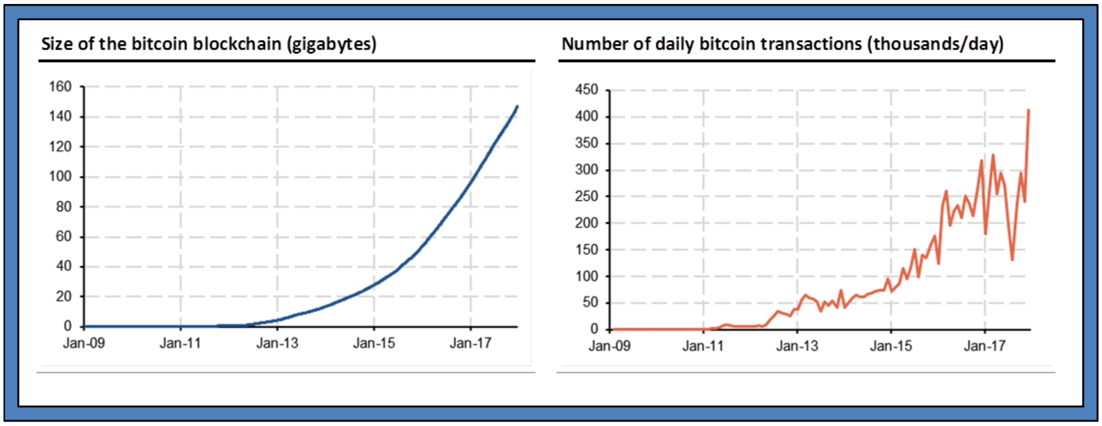
Layer 2: Blockchains

Having introduced hash functions and digital signatures, we can now reintroduce blockchains – the second layer in the bitcoin system. The bitcoin blockchain, like other blockchains, is first and foremost an accounting system, but differ from traditional systems by their decentralized nature.

<u>Blockchains are First and Foremost Accounting Systems</u>

Strictly speaking, a blockchain is a file-like historical record of all past transactions. As for accounting ledgers, entries are sequential, sorted chronologically such that each entry has an antecedent and a descendant. The bitcoin blockchain – that is, the entire history of all bitcoin transactions – can be downloaded as a single file and can fit on most computers. As the number of daily transactions increases, the size of the blockchain will continue to grow as well. Please see Figure 21.

Figure 21



Source: Blockchain.info.

Unlike traditional ledgers however, each entry is uniquely identified by its hash – where the hash is computed from the transaction's characteristics (e.g., sender, receiver, amount…) through the SHA-256 hash function. The hash of a transaction is also a function of the previous transaction's hash.

By way of illustration, we reproduce a simplified blockchain in the below spreadsheet-like figure in Figure 22 on the next page. The spreadsheet (ledger) has five columns, and each transaction is defined by the sender's name (column A), the recipient's name (column B), the transaction amount and signature (column C and D) – and finally its hash (column E). The signature is itself a string of characters and refers to the digital signature generated using the sender's private key.

Figure 22

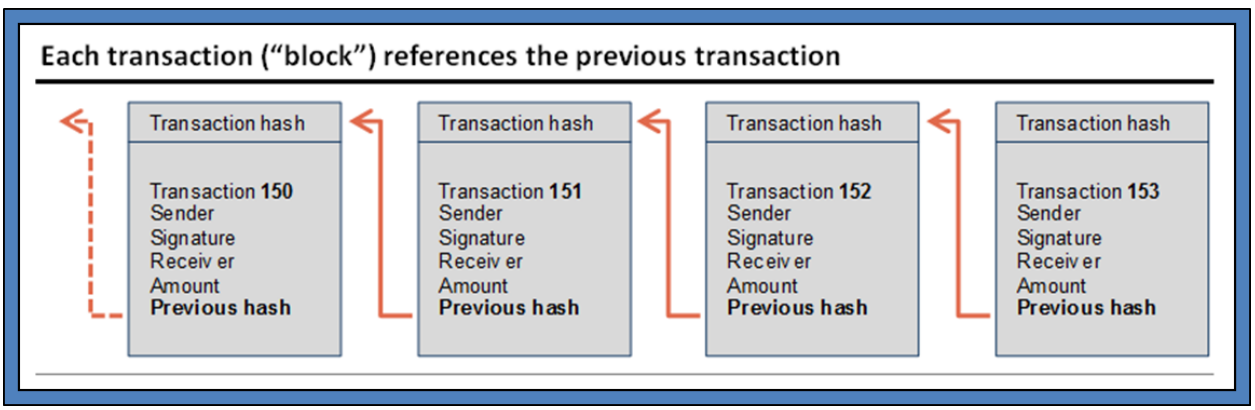
A simplified blockchain implemented in a spreadsheet

	A	B	C	D	E
1	Sender	Receiver	Amount	Signature	Hash
2	David	Nora	10 coins	****	bacbf9c5bf402a8759f577efb49b86d15d65d1a858766612ad15d30268ad2d94
3	Sophie	Mike	20 coins	****	49893f283ea4f2a18b911ef67e1b2535635f5ddfca01573acc74a99132a15c0f
4	Celine	Mark	5 coins	****	=HASH(E3&A4&B4&C4&D4)
5					

Source: SG Cross Asset Research/Commodities.

Importantly, and as noted above, the hash of each transaction (column E) includes the previous transaction's own hash as input. For example, the hash of the third transaction (line 4) is computed using all its features (sender and receiver's name, amount and signature) as well as the hash of the previous transaction on line 3. Likewise, the hash on line 3 refers to the hash on line 2. This way, each transaction iteratively refers the entire history of transactions in its own hash. We illustrate this chaining between blocks in Figure 23 below.

Figure 23



Source: SG Cross Asset Research/Commodities.

The usefulness of including the previous transaction's hash in the subsequent transaction lies with the interdependence created between transactions. Since a transaction's hash acts as a fingerprint, any change to a transaction's content also changes all subsequent transactions. Suppose for instance that a malevolent user – say Sophie – maliciously changed a transaction and claimed to have transferred ten coins rather than original 20. That single change (on line 3 in Figure 24 on the next page) impacts the entire set of subsequent transactions and makes it obvious that an entry has been changed.

Figure 24

Sophie tempers with the ledger on line 3 but all subsequent transactions change

	A	B	C	D	E
1	Sender	Receiver	Amount	Signature	Hash
2	David	Nora	10 coins	****	bacbf9c5bf402a8759f577efb49b86d15d65d1a858766612ad15d30268ad2d94
3	Sophie	Mike	20 coins	****	49893f283ea4f2a18b911ef67e1b2535635f5ddfca01573acc74a99132a15c0f
4	Celine	Mark	5 coins	****	4023571f7adf467c1b465d23319ac676d7753fdf4fa5793c67483ab503cca0ca
...					
1500	Youssef	Vladimir	30 coins	****	fbe5d2bf0cea4b2c8de9538f13c6b60785136bc19bd9cef6228f337391d1771d

	A	B	C	D	E	
1	Sender	Receiver	Amount	Signature	Hash	
2	David	Nora	10 coins	****	bacbf9c5bf402a8759f577efb49b86d15d65d1a858766612ad15d30268ad2d94	✔
3	Sophie	Mike	10 coins	****	7791a14a610e149b2d141c9d19d61d7d157fa369d7c4eb7d074a316ed33a3c1c	✗
4	Celine	Mark	5 coins	****	88aadb36a77d7facc9e2abd2a972da8c78077a805bbc6ff97b03d944ea70cc24	✗
...						
1500	Youssef	Vladimir	30 coins	****	b7f39b82ccd202b83f23e13cae55c00d420fd2fbf73d9ad65337dfd408f23f7b	✗

Source: SG Cross Asset Research/Commodities.

Importantly, the blockchain is a history of transactions rather than a snapshot of account balances. In order to see the balance of an account at a specific moment in time, one instead needs to sum together all the transactions in which that account was involved. The blockchain concept is summarized in Box 2.

Box 2

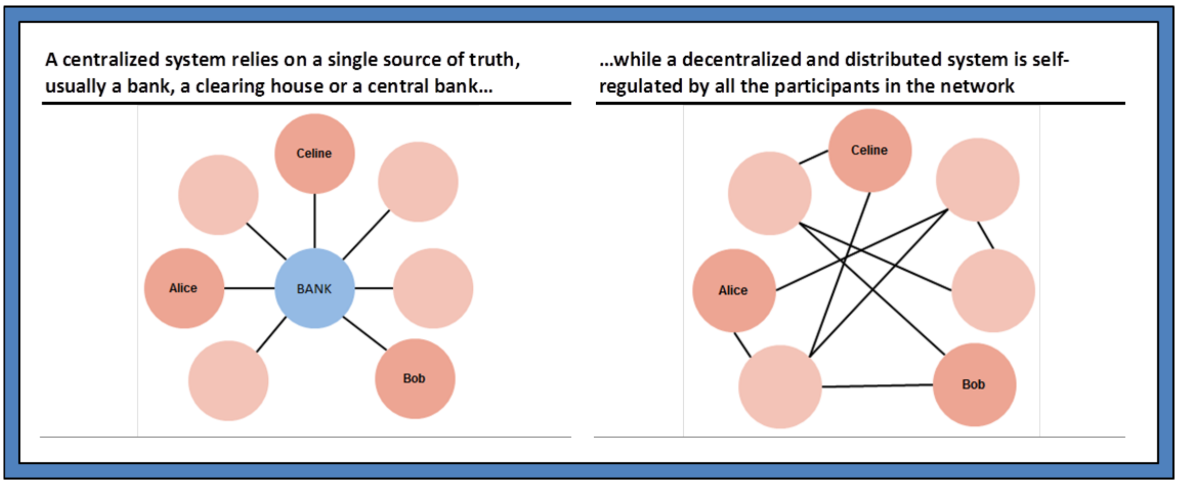
Summary: blockchains
Blockchains are ledger-like data structures in which each entry makes a reference to the previous entry, regardless of whether these are related. This is a key concept in blockchains, as it underlies the **immutability** of the blockchains: no entry can be tampered with unless all subsequent entries are also amended.

Layer 3: Distribution and Decentralization

The above spreadsheet-like example is still an oversimplified example of a real-life blockchain, but the key difference lies in the centralization of the ledger. Indeed, in the above example, one party maintains and updates the ledger, adding entries over time and the integrity of the entire history hinges on one party. Moreover, the above example does not address the question of how coins are initially created nor does it explain how transactions are recorded in the final ledger. Finally, and importantly, the above example overlooks the fact that blockchain tokens (e.g., bitcoins) ultimately acquire monetary value through a process known as bootstrapping.[3]

In this section, therefore, we show how blockchains like bitcoin solve these problems through an elegant combination of cryptography and game theory. In practice, no single-party controls the ledger, and many copies of the ledger are simultaneously and competitively updated by a network of participants known as miners. As shown in the illustration in Figure 25, modern blockchains, unlike traditional ledgers, are distributed systems, and there is no centralized source of truth (i.e., ledger.) Instead, the source of truth is determined through a reconciliation process known as consensus. Finally, to ensure the ledger's immutability (and irreversibility of transactions), large amounts of computing power are required to amend the ledger in a process known as mining. We address each of these areas below.

Figure 25



Source: SG Cross Asset Research/Commodities.

The Challenges of Decentralization

Aspects of decentralization percolate through modern blockchains at different levels in the architecture: as briefly stated above, identity management is fully decentralized on the bitcoin blockchain through the self-generation of public-private keys. Furthermore, all participants ("nodes") on the network can, at any time, replicate a copy of the history of transactions and verify its integrity. Participants can furthermore append to the blockchain through a competitive process known as mining, which we explain below.

The key challenge for decentralized systems like blockchains is to achieve consensus – a state in which the majority of participants agree on the value of their shared resource (e.g., which transactions have been validated.) The way in which the network of participants achieves consensus is known as the protocol. The protocol is a set of rules to which participants agree to abide. Theory and practice suggest consensus for decentralized systems is hard to achieve for a number of reasons: for example, some participants in the network may be unable to voice their opinion, others may have malicious intentions and others still may be outright unaware of the proposed change. We refer interested readers to Box 3 on the next page for an example.

Box 3

Two Generals' paradox

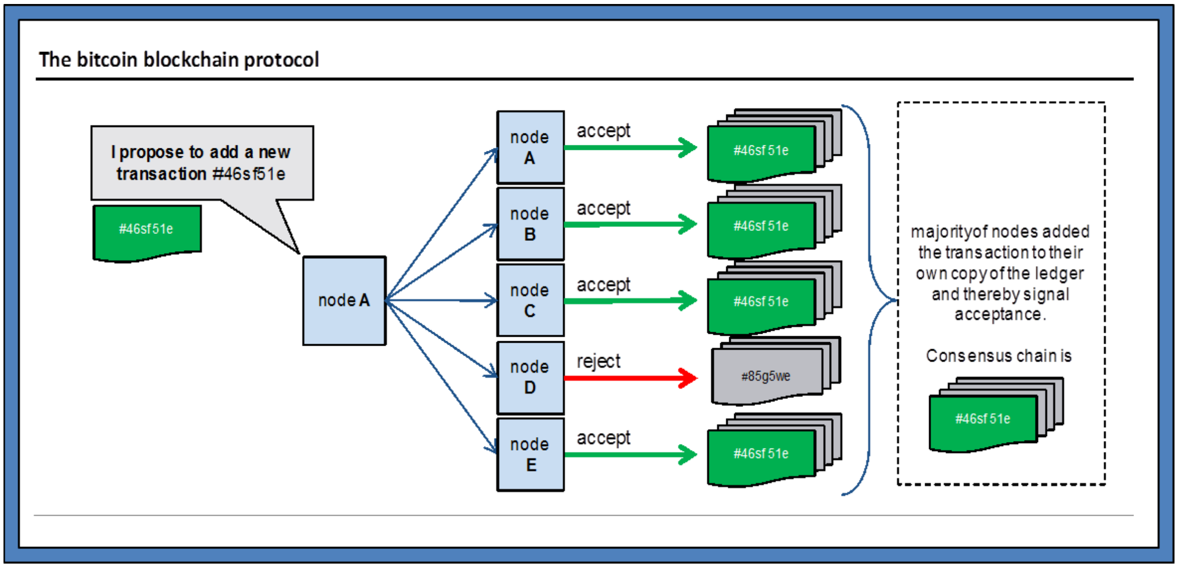
In computer and information science, the difficulty with which a network of participants achieves consensus can be illustrated through a thought-experiment famously known as the *Two Generals' paradox*: two armies, each led by a different general, are preparing to attack a city. For the attack to succeed, both armies must attack simultaneously, or else the lone attacker will be defeated and killed. They must therefore communicate and agree on a time ("consensus"), but importantly, each general must know that the other knows for the attack to succeed. If General A sends General B instructions to attack, he may doubt the latter received the instructions. While General B may send confirmation of the instructions, he in turn may doubt the other general ever received this confirmation – and so forth. A potentially infinite number of messages are required to achieve consensus.

The Rules of the Game: Distributed Consensus

Bitcoin's protocol – its set of rules – is designed such that, at each stage, an active node earns the right to propose adding new transactions it has heard of to the blockchain. Other active participants in the network examine this proposal and verify the transaction's validity – including the sender's signature and the ownership of the tokens being transferred. Each participant individually signals acceptance or rejection of the newly proposed transaction by adding it (or not) to its own copy of the ledger: the network has reached a new consensus.

For example, suppose Mark wanted to send Sophie bitcoins he owned. Mark (node A in Figure 26 on the next page) proposes this new transaction to the network. All other nodes examine the proposal and verify the authenticity of the transaction's signature as well as the existence of the bitcoins Mark claims to own. The participants then accept or reject the transaction by either adding it or not to their own copy of the blockchain. When the majority of the other participants add (or refuse to add) the transaction to their version of the blockchain, then we say the network has achieved consensus. The length of the blockchain increases by one transaction. And as such, the longest observable chain, shared by the majority of nodes, becomes the consensus blockchain.

Figure 26

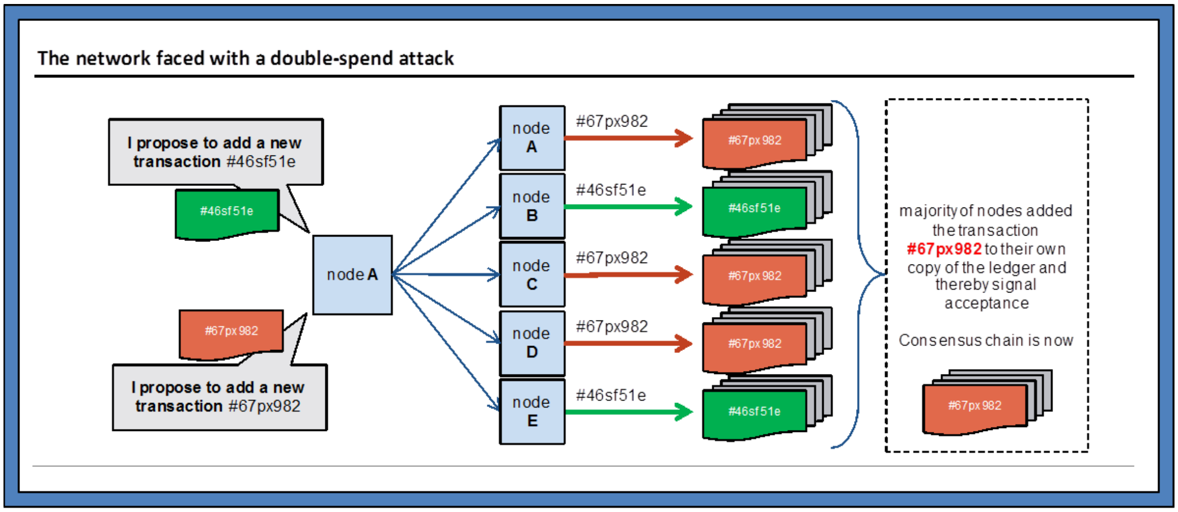


Source: SG Cross Asset Research/Commodities.

Suppose now Mark broadcasts another transaction simultaneously, claiming to send the same bitcoins he sent Sophie to someone else. This is known as the double-spend attack. From the point of view of other participants, both transactions are valid as both have valid signatures and proven funds. And because nodes do not know which transaction came first chronologically, nor which one is supposedly accurate, there is really no way for the network to discriminate among transactions. Instead, each node treats the first proposal they hear about as the only transaction they need to examine. And when the majority of nodes elects to keep one transaction rather than another, that transaction is entered into the consensus chain and the other one is discarded.

For example, node A in Figure 27 on the next page simultaneously proposes two transactions (red and green), both of which claim to transfer the same funds. Nodes A, C and D decide to accept the former, while B and E accept the latter. The consensus chain arbitrarily accepts the red transaction and discards the green. Any subsequent attempt to add the green transaction would now fail, as the proposed transaction's validity would no longer hold (Mark can no longer claim ownership of the funds.)

Figure 27

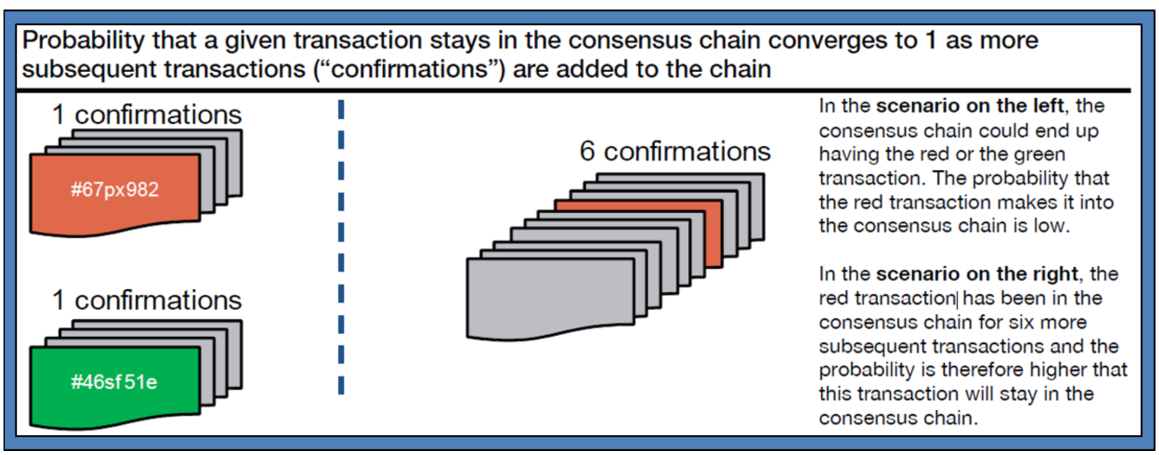


Source: SG Cross Asset Research/Commodities.

In practice, participants group transactions together in bundles known as blocks (hence blockchain.) Each block contains several thousand transactions – but for the purpose of this paper, we will continue to assume that each block contains only one transaction.

In the absence of a central organization, two or more versions of the blockchain may exist side-by-side for a while, but the protocol nevertheless incentivizes nodes to accept the longest valid chain and to discard other valid but shorter versions of the blockchain. As such, as time progresses, participants will accept the biggest blockchain as the ultimate true blockchain. As more entries are added after a given transaction, the probability that the transaction does not remain in the consensus chain therefore diminishes exponentially over time; please see Figure 28.

Figure 28

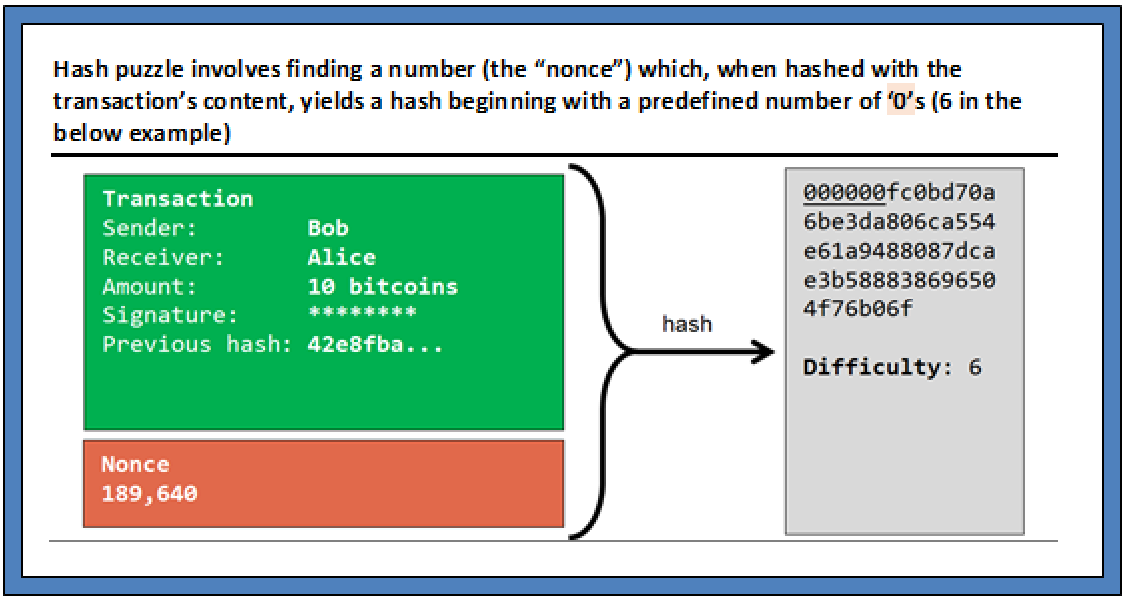


Source: SG Cross Asset Research/Commodities.

Earning your Rights: Proof-of-Work (POW)

We stated above that an active node earns the right to propose adding a new transaction it has heard of to the blockchain. The process through which a node earns this right is known as mining. Mining involves finding a number, called the nonce, which solves a very difficult cryptographic puzzle, the solution to which can only be found by trying a very large number of random values. Specifically, the puzzle involves finding a number, which, when hashed with the transaction's content (sender, receiver…), yields a hash beginning with a predefined number of '0's.[4]

Figure 29



Source: SG Cross Asset Research/Commodities.

For example, suppose Mark, a participant on the network, heard of the above transaction (in green), involving a transfer of ten bitcoins from Bob to Alice. Also, assume that the difficulty is set to 6. As illustrated in Figure 29 above:

1. Mark would first verify the integrity of the transaction by checking if Bob indeed has ten bitcoins to spend.

2. Mark would also check the authenticity of the transaction by verifying the signature.

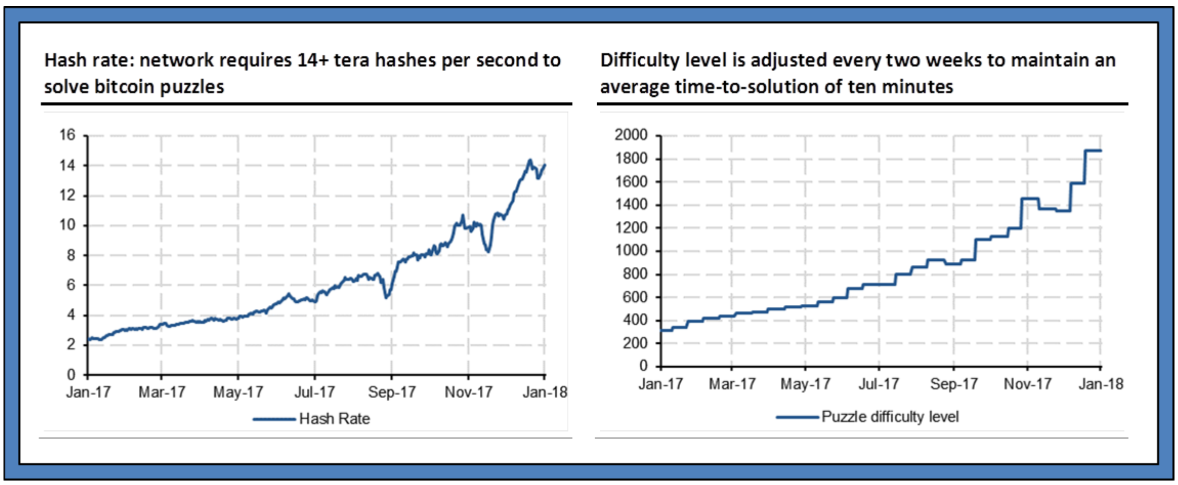
3. Mark then iteratively tries random numbers (1, 2, 3… 189,640) until he finds one which, when hashed together with the transaction's content, yield a hash which begins with at least six '0's.

In the above example, a solution to the problem is 189,640: the hash of the transaction's hash along with that number produces a new hash starting with 000000fc…, which indeed begins with six zeroes. This is only one of many solutions: 6,591,810 is also a solution, for example.

Having solved this puzzle, Mark can now broadcast the transaction along with his solution to the rest of the network. Other participants on the network can verify the transaction as well as Mark's proposed solution, and if the proposed transaction indeed reconciles, they can then update their personal copy of the blockchain using the normal protocol.

Solving the above example is simple and takes less than a minute using a standard computer. In practice, the difficulty is significantly higher, and is adjusted every two weeks such that, on average, a solution is found every ten minutes by the bitcoin network. As of the writing of this article, the network requires the final hash to begin with at least 18 '0's, implying miners must currently try 14 million trillion hashes per second (14,000,000,000,000,000,000,000/second). Please see Figure 30.

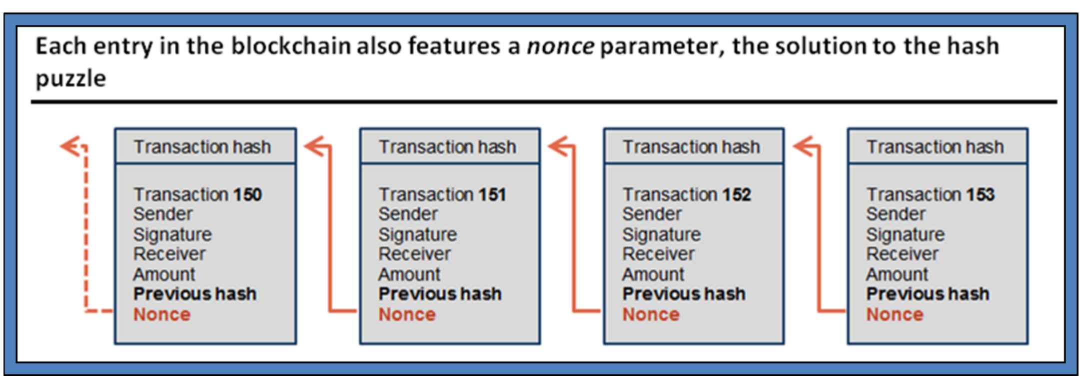
Figure 30



Source: SG Cross Asset Research/Commodities.

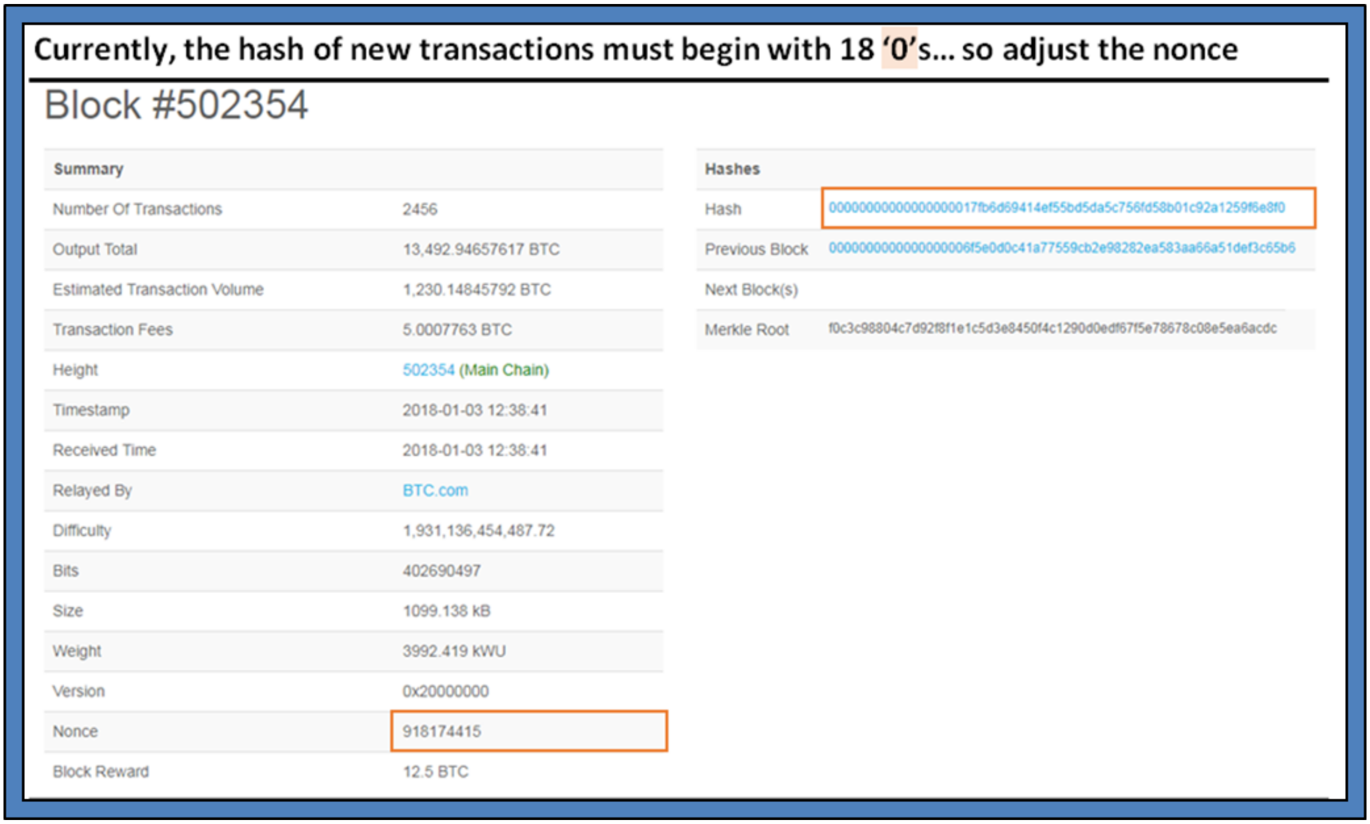
Each record on the bitcoin blockchain therefore also contains the solution of the hash puzzle, and is required to record the transaction on the blockchain. Please see Figure 31 (below) and Figure 32 (on the next page.)

Figure 31



Source: SG Cross Asset Research/Commodities.

Figure 32



Currently, the hash of new transactions must begin with 18 '0's… so adjust the nonce

Block #502354

Summary	
Number Of Transactions	2456
Output Total	13,492.94657617 BTC
Estimated Transaction Volume	1,230.14845792 BTC
Transaction Fees	5.0007763 BTC
Height	502354 (Main Chain)
Timestamp	2018-01-03 12:38:41
Received Time	2018-01-03 12:38:41
Relayed By	BTC.com
Difficulty	1,931,136,454,487.72
Bits	402690497
Size	1099.138 kB
Weight	3992.419 kWU
Version	0x20000000
Nonce	918174415
Block Reward	12.5 BTC

Hashes	
Hash	00000000000000000017fb6d69414ef55bd5da5c756fd58b01c92a1259f6e8f0
Previous Block	0000000000000000006f5e0d0c41a77559cb2e98282ea583aa66a51def3c65b6
Next Block(s)	
Merkle Root	f0c3c98804c7d92f8f1e1c5d3e8450f4c1290d0edf67f5e78678c08e5ea6acdc

Source: SG Cross Asset Research/Commodities, blockchain.info.

The difficulty of finding the solution to a hash puzzle underpins the immutability of the blockchain. If one wanted to temper – or reverse – a past transaction, one would not only need to solve the puzzle of the affected transaction, but also of all subsequent transactions to create a blockchain longer than what other participants currently have. And, as the number of participants increase, the probability of controlling enough computing power to outpace the network falls to zero. In the word of bitcoin's author, Satoshi Nakamoto:

> The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers.

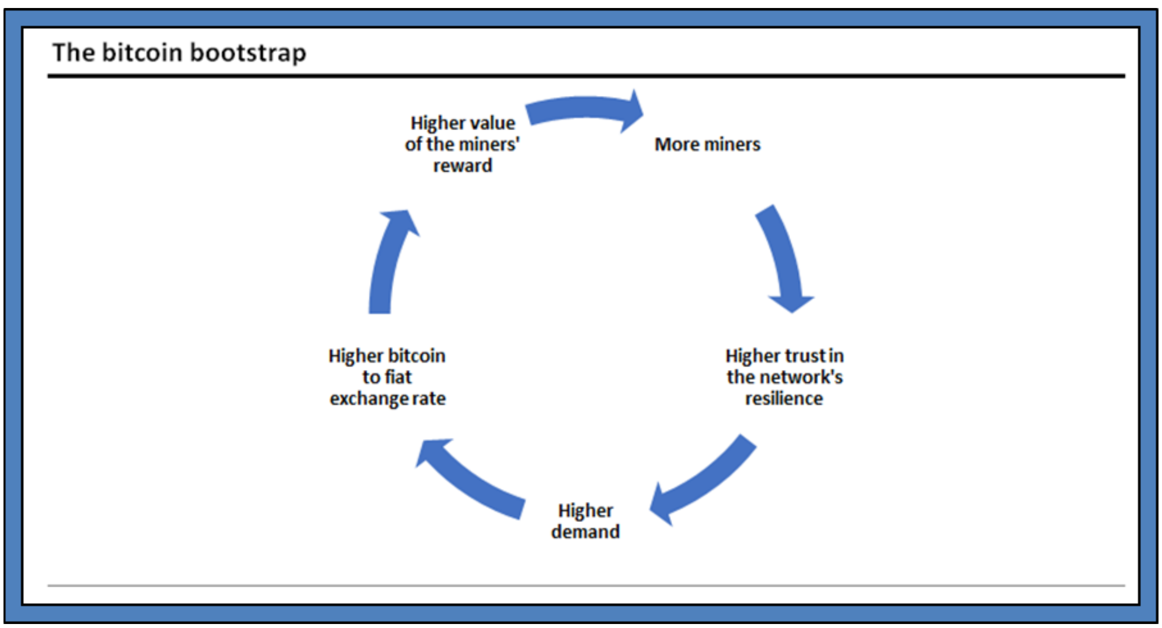
Obviously, solving hash puzzles involves deploying lots of computing power and electricity – and the bitcoin protocol features clever incentives to encourage participants to become involved in this costly process, colloquially known as mining. Indeed, in order to incentivize participants to solve these hash puzzles, the blockchain rewards the miner with a number of bitcoins (currently 12.5 per block of transactions for each hash puzzle they solve.) This reward is created *ex-nihilo*, and is the source of any bitcoin in circulation: stated differently, all bitcoins in circulation were, at one point in time, a reward attributed to a miner. But importantly, the reward is only valuable on the longest blockchain, therefore incentivizing participants to accept the longest chain as the source of truth.

Layer 4: Putting Everything Together – Bootstrapping Bitcoin

Convertibility into fiat currencies is the last crucial element of the system. While miners are rewarded with bitcoins, their electricity and computing costs are however in fiat currencies (e.g., USD, CNY…), and allowing these participants to convert the former into the latter is a key imperative for a healthy mining ecosystem.

Bootstrapping refers to the mutual dependence between demand for bitcoins, mining profitability and trust in the system. Please see Figure 33. As more miners compete to maintain the blockchain, the probability that a transaction can be reversed falls. Therefore, trust in the system's ability to confirm transactions rises. As trust increases in bitcoin, so will demand, which will push the exchange rate higher. And finally, a higher exchange rate makes mining more profitable, hence more attractive.

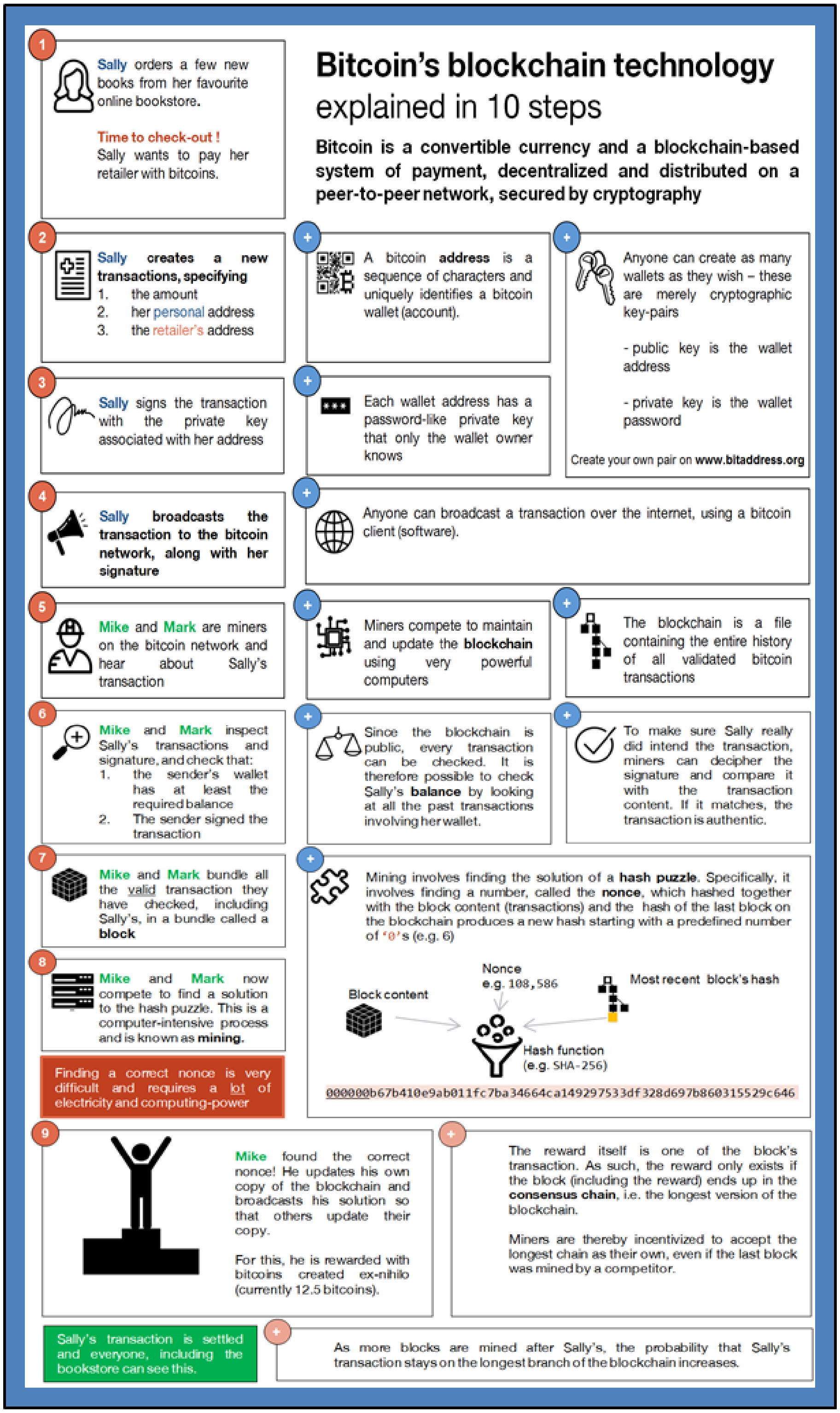
Figure 33



Source: SG Cross Asset Research/Commodities.

In summary, Figure 34 on the next page explains bitcoin's blockchain technology in ten steps.

Figure 34



Note: Icons courtesy of the "Noun Project." Please see the endnotes for attributions.

Source: SG Cross Asset Research/Commodities.

Conclusion

Bitcoin and the underlying blockchain technology are still in their early days. Within the cryptocurrencies space, Bitcoin could be viewed as a proof of concept. The blockchain has demonstrated the feasibility of decentralization and opened the way for many more applications. It is also starting to show its limits. The cost of mining, during which transactions are validated and then recorded on the blockchain, has recently exploded, both in monetary and electricity terms. Other blockchains are already moving to less energy-hungry models.

In this paper, we have tried to address many of the questions about this nascent technology. We stress that the piece is solely an educational piece – we express no opinion, view or endorsement of cryptocurrencies, bitcoin or the blockchain technology.

Endnotes

1 Tokens are a representation of a particular asset or utility, whereas a coin is in and of itself the asset. For example, a government could use a token blockchain to manage its land registry.

2 Tokens can be used with smart-contracts, which allow for the automatic transfer of ownership contingent on a trigger (e.g., weather.)

3 This is a distinct concept from statistical bootstrapping.

4 Technically, hashes are base-16 numbers, and solving the hash puzzle involves finding a hash smaller than a specified threshold.

*Icon Attributions: Woman by Gregor Cresnar from the Noun Project; medical form by Royyan Wijaya from the Noun Project; Bitcoin Address by useiconic.com from the Noun Project; house keys by b farias from the Noun Project; autograph by Royyan Wijaya from the Noun Project; OTP by Ayushi Bhandari from the Noun Project; internet by Asimbla from the Noun Project; miner by ProSymbols from the Noun Project; CPU by Aiden Icons from the Noun Project; Blockchain by Jason D. Rowley from the Noun Project; Zoom In by Weltenraser from the Noun Project; Puzzle by IconDots from the Noun Project; Funnel by Gregor Cresnar from the Noun Project; Shared Hosting by b farias from the Noun Project; winner by Hopkins from the Noun Project.

This article is a republication of Société Générale Cross Asset Research, *Commodity Compass*, January 10, 2018.

Author Biographies

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

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

MICHAEL HAIGH, Ph.D.
Managing Director and Global Head of Commodities Research, Société Générale (U.S.)

Dr. Michael Haigh is Managing Director and Global Head of Commodities Research for Société Générale and is based in NYC. For 2017, 2016, 2015, 2014 and 2013, SG CIB has been voted by the industry as the Best Overall in Commodity Research in both *Risk* and *Energy Risk*, two highly respected publications dedicated to risk management, trading and regulation for the global commodity markets. Immediately prior to running the Global Commodities Research team, Dr. Haigh was Global Head of Commodities Research at Standard Chartered Bank, based in Singapore. Prior to joining Standard Chartered Bank, Dr. Haigh held the positions of Managing Director at K2 Advisors LLC, a Global Hedge Fund of Funds where he focused on Commodity Research/Investing and also as Managing Director and U.S. Head of Commodities Research and Strategy at Société Générale in NYC. Dr. Haigh also spent several years as the Associate Chief Economist at the U.S. Commodity Futures Trading Commission (CFTC). He began his career in academia and held a position as a tenured Associate Professor of Economics at the University of Maryland, U.S. Dr. Haigh has taught graduate (M.B.A.) & undergraduate derivative courses at several universities including NYU Stern School of Business, Johns Hopkins University and George Washington University and has supervised numerous Ph.D. dissertations on the commodity and financial markets. He has published numerous scholarly research papers on commodity and derivative markets in several leading journals including the *Journal of Finance*, *Journal of Business*, *Journal of Futures Markets*, and the *Journal of Applied Econometrics*. Dr. Haigh holds a Ph.D. in Economics with a minor in Statistics from North Carolina State University.

DAVID SCHENCK
Commodities Analyst, Société Générale (U.K.)

Mr. David Schenck is a Commodities Analyst based in London. He joined Société Générale in 2016. Mr. Schenk holds a Master's degree in International Finance from HEC Paris (France) and a Bachelor's degree in Economics from Trinity College Dublin (Ireland).

KLAUS BAADER
Global Chief Economist, Société Générale (U.K.)

Mr. Klaus Baader is Global Chief Economist for Société Générale and based in London. Before relocating to London in 2018, he was Chief Economist Asia Pacific, based in Hong Kong, and prior to that, Chief Euro Area Economist in London. He joined Société Générale in July 2009 from Merrill Lynch where he had been Chief Europe Economist since 2006. Previously, he was at Lehman Brothers for 10 years, latterly as Senior Europe Economist. He has also held positions at UBS and Deutsche Bank. Mr. Baader began his career at Salomon Brothers in 1989 after studying Economics and Political Science at the University of Cologne and the London School of Economics. He received his B.Sc. in Economics from the LSE in 1988 and completed his Master's in Economics in 1989.

How Futures Trading Changed Bitcoin Prices

Galina Hale, Ph.D.
Research Advisor, Federal Reserve Bank of San Francisco

Arvind Krishnamurthy, Ph.D.
The John S. Osterweis Professor of Finance, Stanford Graduate School of Business

Marianna Kudlyak, Ph.D.
Research Advisor, Federal Reserve Bank of San Francisco

Patrick Shultz
Doctoral Candidate, Wharton School, University of Pennsylvania and
Former Research Associate, Federal Reserve Bank of San Francisco

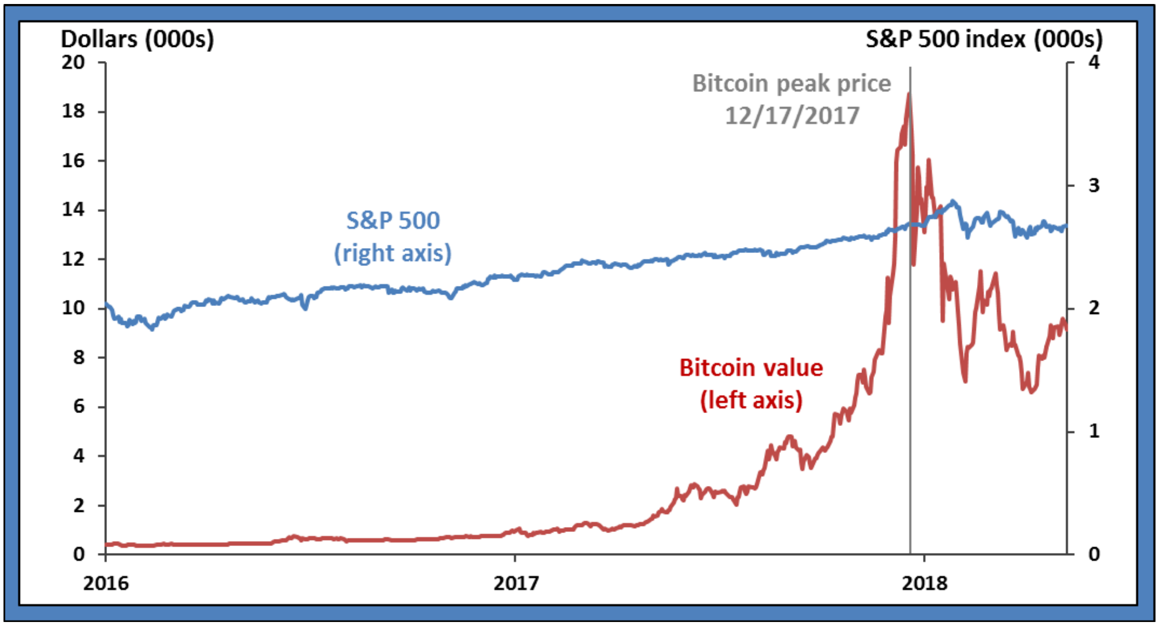
---

From Bitcoin's inception in 2009 through mid-2017, its price remained under $4,000. In the second half of 2017, it climbed dramatically to nearly $20,000, but descended rapidly starting in mid-December. The peak price coincided with the introduction of bitcoin futures trading on the Chicago Mercantile Exchange. The rapid run-up and subsequent fall in the price after the introduction of futures does not appear to be a coincidence. Rather, it is consistent with trading behavior that typically accompanies the introduction of futures markets for an asset.

Bitcoin is a "cryptocurrency" – a digital currency that is not backed by any tangible or intangible assets of intrinsic value. After its launch in January 2009, the dollar price of a bitcoin remained under $1,150 until February 22, 2017, when it increased exponentially for about 10 months, as shown in Figure 1 on the next page. This explosive growth ended on December 17, 2017, when bitcoin reached its peak price of $19,511. Notably these dynamics aren't driven by overall market fluctuations, as shown by comparison with the Standard & Poor's 500 stock index.

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

Figure 1
Bitcoin Prices and S&P 500 Stock Index



Source: The Bloomberg.

The peak bitcoin price coincided with the day bitcoin futures started trading on the Chicago Mercantile Exchange (CME). In this article, we argue that these price dynamics are consistent with the rise and collapse of the home financing market in the 2000s, as explained in Fostel and Geanakoplos (2012). They suggested that the mortgage boom was driven by financial innovations in securitization and groupings of bonds that attracted optimistic investors; the subsequent bust was driven by the creation of instruments that allowed pessimistic investors to bet against the housing market. Similarly, the advent of blockchain introduced a new financial instrument, bitcoin, which optimistic investors bid up, until the launch of bitcoin futures allowed pessimists to enter the market, which contributed to the reversal of the bitcoin price dynamics.

What is Bitcoin?

Bitcoin with a capital B is a decentralized network that relies on a peer-to-peer system, rather than banks or credit card companies, to verify transactions using the digital currency known as bitcoin with a lowercase b. The first bitcoin was "mined" in 2009 after the anonymous person or group named Satoshi Nakamoto published a proof of concept for a currency that uses cryptography, rather than reliable third parties (Nakamoto, 2008). Blockchain, the underlying infrastructure and ledger of bitcoin, provides a secure platform for two parties to do business with one another (Chiu and Koeppl, 2017 and Berentsen and Schar, 2018).

Bitcoin miners contribute computing resources to verify bitcoin transactions and hence maintain blockchain. They are compensated for sharing their computing resources with new bitcoins. The total numbers of bitcoins to be mined has been arbitrarily set at 21 million. When this volume is reached – estimates suggest in 2140 – miners will be compensated by transaction fees rather than new bitcoins (Nian and Chuen, 2016).

Bitcoin Price Dynamics from the End of 2017 to Early 2018

When discussing the price of a currency or an asset like bitcoin, it is useful to separate transactional demand, which arises from using bitcoins in transactions such as purchases of goods and services, from speculative demand, which arises when people are buying bitcoins in the hope that their value will increase. Speculative demand is basically a bet on the price of the underlying asset or currency increasing, because the investor does not need the asset itself. For most currencies and assets, investors have ways to bet on the increase or decline in their value using a variety of financial instruments based on the asset or a currency, so-called financial derivatives.

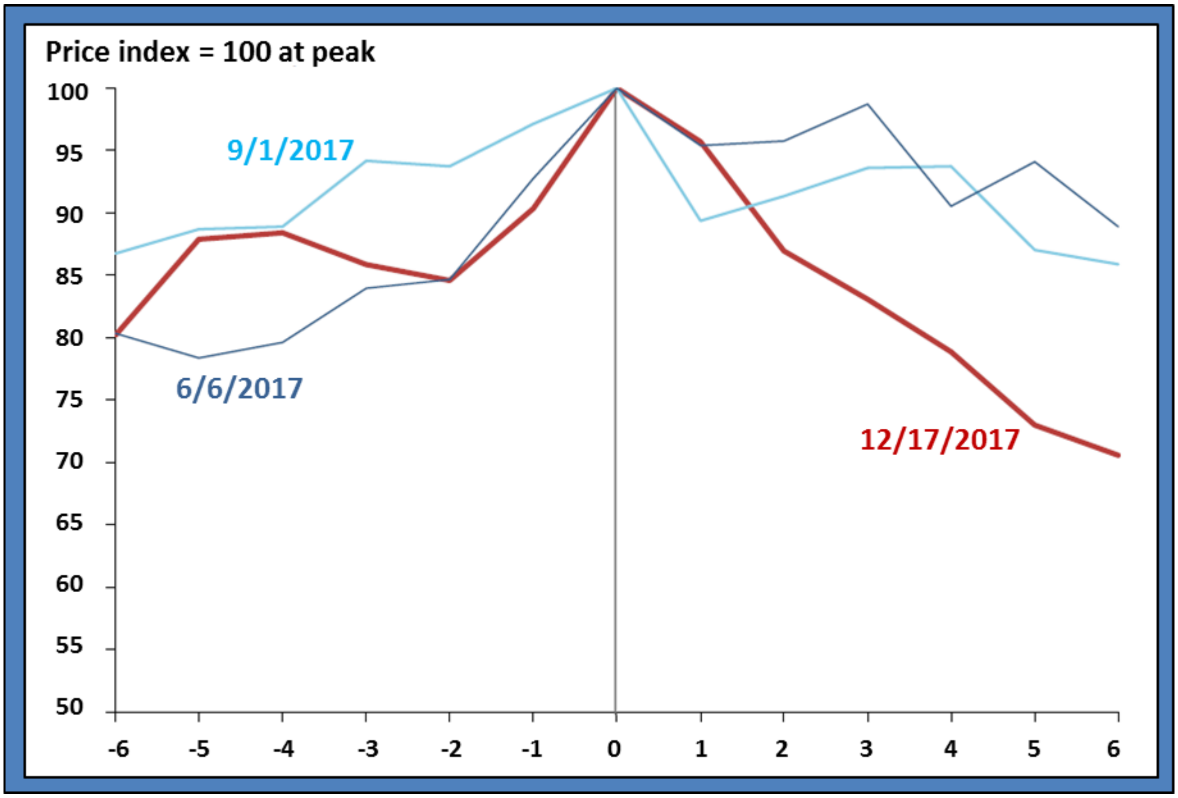
Before December 2017, there was no market for bitcoin derivatives. This meant that it was extremely difficult, if not impossible, to bet on the decline in bitcoin price. Such bets usually take the form of short selling, that is selling an asset before buying it, via forward or future contracts, swaps, or a combination. Betting on the increase in bitcoin price was easy—one just had to buy it. Speculative demand for bitcoin came only from optimists, investors who were willing to bet money that the price was going to go up. And until December 17, 2017, those investors were right: as with a self-fulfilling prophecy, optimists' demand pushed the price of bitcoin up, energizing more people to join in and keep pushing up the price. The pessimists, however, had no mechanism available to put money behind their belief that the bitcoin price would collapse. So they were left to wait for their "I told you so" moment.

This one-sided speculative demand came to an end when the futures for bitcoin started trading on the CME on December 17, 2017. Although the Chicago Board Options Exchange (CBOE) had opened a futures market a week earlier on December 10, trading was thin until the CME joined the market. Indeed, the average daily trading volume the month after the CME issued futures was approximately six times larger than when only the CBOE offered these derivatives.

With the introduction of bitcoin futures, pessimists could bet on a bitcoin price decline, buying and selling contracts with a lower delivery price in the future than the spot price. For example, they could sell a promise to deliver a bitcoin in a month's time at a lower price than the current spot price and hope to buy a bitcoin during the month at an even lower price to make a profit. With offers of future bitcoin deliveries at a lower price coming through, the order flow necessarily put downward pressure on the spot price as well. For all investors who were in the market to buy bitcoins for either transactional or speculative reasons and were willing to wait a month, this was a good deal. The new investment opportunity led to a fall in demand in the spot bitcoin market and therefore a drop in price. With falling prices, pessimists started to make money on their bets, fueling further short selling and further downward pressure on prices.

Figure 2 on the next page shows the three largest bitcoin price declines in 2017. We scale the three series so that the peak values are equal to 100 on the peak event days. Hence, each point on the figure can be interpreted as a percent of the peak value. The horizontal axis represents the number of days before and after the peak dates. The price decline following the issuance of bitcoin futures on the CME (red line) is clearly larger than in the previous two reversals. Additionally, the two earlier decreases in prices returned to pre-crash levels in about a month. As of the writing of this article, the bitcoin price had not returned to its pre-futures peak.

Figure 2
Comparison of Three Largest Bitcoin Price Declines in 2017



Sources: The Bloomberg; Authors' calculations.

This is not the first time that markets observed a turning point following the introduction of a new instrument, as Fostel and Geanakoplos (2012) show for the more complex mortgage-backed securities market. The mechanism they describe hinges on the same driving force of optimistic and pessimistic traders.

Why, then, did the price of bitcoin fall somewhat gradually rather than collapse overnight? The answer to this is difficult. It could be that pessimistic investors lack the attention, willingness, or ability to enter the market on the first day or week of trading. Consistent with this assertion, the total volume of transactions in the CME futures market started very low, with an average trading volume of contracts promising to deliver approximately 12,000 bitcoins during the first week of trading, relative to the estimated spot market turnover of 200,000 bitcoins.

Is There a Fundamental Price of Bitcoin?

So where is the price of bitcoin going? This is a very difficult question, and we do not pretend to be able to forecast bitcoin prices, nor will we offer any guesses. Instead, we outline a few factors that may affect the fundamental price of bitcoin, which is where we would expect the price to go in the long run, once speculative demand by optimists and pessimists balances out.

The supply of bitcoins is determined by the volume of bitcoin currently in circulation and the additional volume to be mined. The decision to mine a bitcoin depends on the cost and benefit from mining. Hayes (2015) estimated a bitcoin mining cost in 2015 of around $250, which was close to the bitcoin price at the time. More generally, however, the mining cost of bitcoin should not affect its value any more than the cost of printing regular currency affects its value – basically not at all.

Given that there is no actual asset that backs the value of bitcoin and it doesn't provide a natural hedge as insurance against sharp moves in any other asset's value, what will eventually determine the "fundamental" price of bitcoin is transactional demand relative to supply. We know that bitcoin is used as a means of exchange in a number of markets. The amount of bitcoins needed for these markets to function constitutes transactional demand. The supply growth of bitcoin is becoming more limited as the mining price increases. If transactional demand grows faster than supply, we would expect the price to grow.

Transactional demand in turn depends on a number of factors. One is the availability of substitutes. If a different cryptocurrency becomes more widely used as a means of exchange in the markets currently dominated by bitcoin, demand for bitcoin may drop precipitously because these tend to be winner-takes-all markets. Second, if traditional financial institutions become more willing to accept bitcoin as collateral, a means of payment, or a direct investment, demand may increase substantially. Finally, official recognition and regulatory acceptance of bitcoin as a means of payments would increase its circulation, while regulatory constraints or introduction of transaction fees may reduce it.

Conclusions

We suggest that the rapid rise of the price of bitcoin and its decline following issuance of futures on the CME is consistent with pricing dynamics suggested elsewhere in financial theory and with previously observed trading behavior. Namely, optimists bid up the price before financial instruments are available to short the market (Fostel and Geanakoplos, 2012). Once derivatives markets become sufficiently deep, short-selling pressure from pessimists leads to a sharp decline in value. While we understand some of the factors that play a role in determining the long-run price of bitcoin, our understanding of the transactional benefits of bitcoin is too imprecise to quantify this long-run price. But as speculative dynamics disappear from the bitcoin market, the transactional benefits are likely to be the factor that will drive valuation.

Endnotes

Reprinted from the Federal Reserve Bank of San Francisco's *FRBSF Economic Letter*, 2018-12, dated May 7, 2018, https://www.frbsf.org/economic-research/publications/economic-letter/2018/may/how-futures-trading-changed-bitcoin-prices/. The opinions expressed in this article do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or of the Board of Governors of the Federal Reserve System.

References

Berentsen, A. and F. Schar, 2018, "A Short Introduction to the World of Cryptocurrencies," Federal Reserve Bank of St. Louis *Review,* Vol. 100, No. 1, pp. 1 - 16.

Chiu, J. and T. Koeppl, 2017, "The Economics of Cryptocurrencies—Bitcoin and Beyond," Queen's Economics Department Working Paper 1389.

Fostel, A. and J. Geanakoplos, 2012, "Tranching, CDS, and Asset Prices: How Financial Innovation Can Cause Bubbles and Crashes*," American Economic Journal: Macroeconomics,* Vol. 4, No. 1, pp. 190 - 225.

Hayes, A., 2015, "A Cost of Production Model for Bitcoin," Working Paper 05/2015, Department of Economics, The New School for Social Research.

Nakamoto, S., 2008, "Bitcoin: A Peer-To-Peer Electronic Cash System," Unpublished paper.

Nian, L. and D. Lee Kuo Chuen, 2016, "Introduction to Bitcoin," in D. Lee Kuo Chuen (ed) Handbook of Digital Currency: Bitcoin, Innovation, Financial Instruments, and Big Data, London: Academic Press, pp. 19 - 21.

Author Biographies

GALINA HALE, Ph.D.
Research Advisor, Federal Reserve Bank of San Francisco

Dr. Galina Hale is a Research Advisor in the Economic Research Department of the Federal Reserve Bank of San Francisco where she has worked since 2006. Prior to joining the Federal Reserve, she was an Assistant Professor in the Economics Department of Yale University. She also was a visiting assistant professor in the Department of Economics at Stanford University and at the Haas School of Business at UC Berkeley. She earned her B.A. in Economics from Moscow State University and an M.A. in Economics from the New Economic School in Russia. She received her Ph.D. in Economics in 2002 from UC Berkeley.

ARVIND KRISHNAMURTHY, Ph.D.
The John S. Osterweis Professor of Finance, Stanford Graduate School of Business

Dr. Arvind Krishnamurthy is the John S. Osterweis Professor of Finance at the Stanford Graduate School of Business and a research associate at the National Bureau of Economic Research. Dr. Krishnamurthy's research interests include financial intermediation, debt markets, housing markets, financial crises, monetary policy, and financial regulation. His research on financial crises and monetary policy has received national media coverage and been cited by central banks around the world. He received his Ph.D. from MIT and his undergraduate degree from the University of Pennsylvania.

MARIANNA KUDLYAK, Ph.D.
Research Advisor, Federal Reserve Bank of San Francisco

Dr. Marianna Kudlyak is a Research Advisor at the Federal Reserve Bank of San Francisco where she has worked since 2016. Prior to joining the Federal Reserve Board of San Francisco she was an Economist at the Federal Reserve Board of Richmond. She also has been a visiting scholar at UC Berkeley; UT Austin; CIREQ, Montreal, Canada; and at the Federal Reserve Board of

St. Louis. Dr. Kudlyak has published several articles in various academic journals. She received her Ph.D. in Economics from the University of Rochester in 2009.

PATRICK SCHULTZ
Doctoral Candidate, Wharton School, University of Pennsylvania

Mr. Patrick Shultz is a former Research Associate in the Economic Research Department of the Federal Reserve Bank of San Francisco in addition to being a doctoral candidate at the Wharton School, University of Pennsylvania.

Blockchain for Physical Commodity Markets - A Realist's Perspective

Julie Lerner
Chief Executive Officer, PanXchange

Ms. Julie Lerner, Chief Executive Officer, PanXchange, participated in the industry panel during the J.P. Morgan Center for Commodities' 2nd International Commodities Symposium, which was held at the University of Colorado Denver Business School on August 14 and August 15, 2018.

There is a lot of excitement about blockchain. Advocates believe it will solve inefficiencies in everything from stocks and bonds to production and delivery of commodities. Some even claim it will end global poverty (Gramm and deSoto, 2018).

I am skeptical, however, about the current feasibility of implementing blockchain in commodity trading. I am not a specialist in this new technology, but I have spent my career in the commodity trading business. I know from personal experience that it will be extremely difficult to garner industry-wide support for such a massive change in technology. Below, I'll outline some of the primary obstacles standing in the way of blockchain adoption in this industry.

Industry Reticence

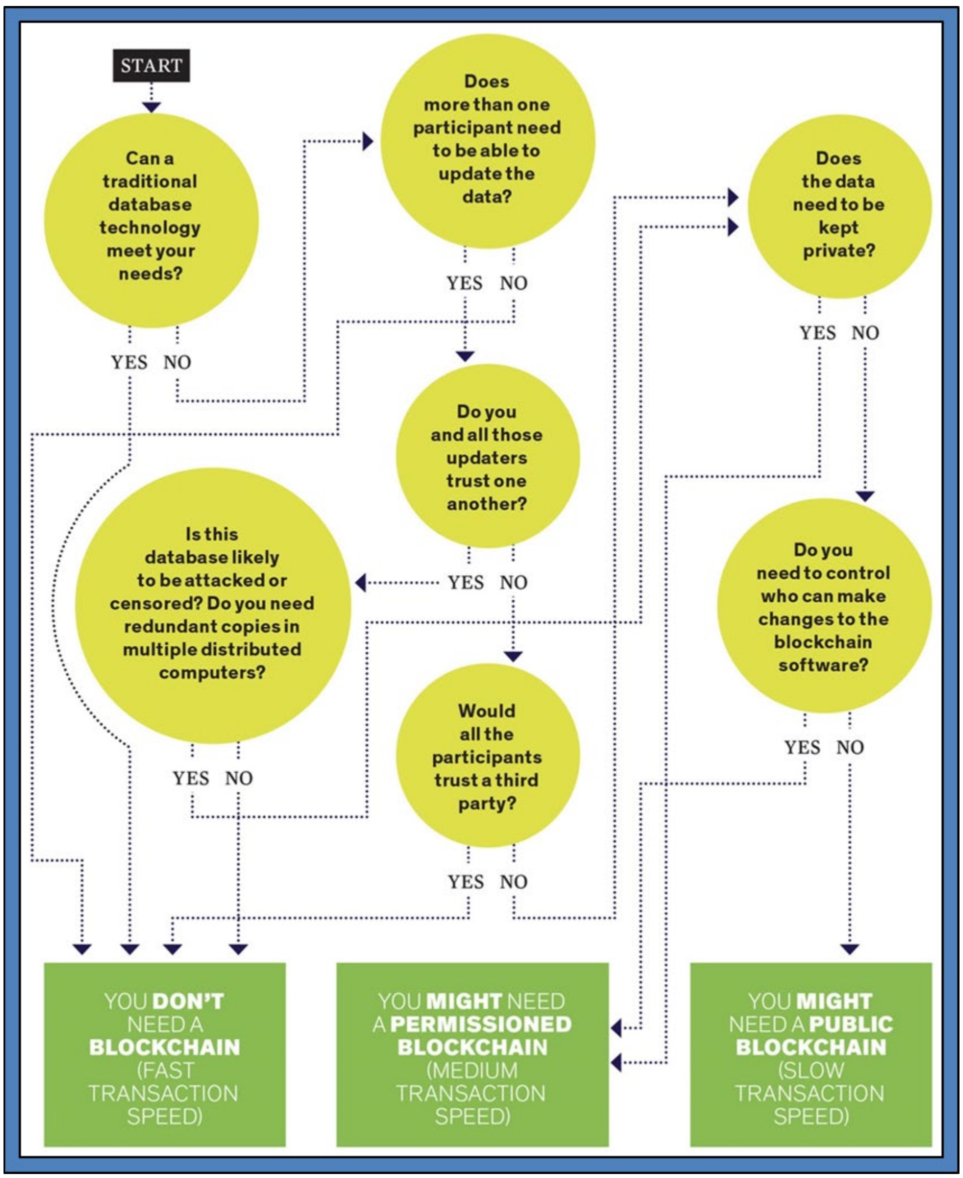
The first issue is the industry itself. Getting commodities participants to accept the "switching cost" associated with adopting new technologies is difficult – just look how long it has taken professional traders and institutions to embrace new methods of trading. The Chicago Mercantile Exchange only shuttered open-outcry trading in 2015, and still has pit trading on some options on futures. Or note how

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

much disruption there was among energy traders in 2017 when AOL Instant Messenger (AIM) was shut down. Years after the rest of the world had moved on to newer methods of communicating, thousands of people in the energy markets were still using AIM to negotiate their trades because that was the platform all their industry peers were using.

The fact is, in most cases a faster, simpler and cheaper database built specifically for an industry's problem will suffice. For more on this, the Institute of Electrical and Electronics Engineers (IEEE), an organization for technology professionals, published a terrific decision tree, which is shown in Figure 1.

Figure 1
Decision Tree



Source of Schematic: Peck (2017).

The key takeaway from Figure 1 and the IEEE article is that for blockchain to work, you need a modicum of trust among the players in the industry. And if you have that, then perhaps there are other databases you all could agree upon that would be more efficient and less costly to implement than blockchain. Given this glacial adoption rate and inherent distrust of new technology, software firms offering distributed ledger technologies will have a difficult time gaining acceptance in this space. As a blockchain vendor, you are a solution looking for a problem. However, there is a better chance of adoption if the technology is distributed by a consortium of industry participants on a private blockchain, i.e., industry participants addressing their own problems. But even then, the question becomes, "Will the industry collectively adopt new technology, rather than stick to simpler and more proven software?"

Interconnected Processes and Unpredictable Occurrences

The second issue is that commodity trading is such a complex ecosystem. There are many layers of the transaction chain that must all work together, each with a lot of nuance. For example, for blockchain to work in physical supply chains, you need the industry to accept one solution in the transportation business for bills of lading, and you need another (or three others) for the quality inspection, verification and origin certification. Presumably, this will come after a banking blockchain is implemented for wire transfers, letters of credit and other payment terms for ultimate transfer of ownership. In a perfect world, all these interconnected processes within physical commodities would adapt and evolve in perfect harmony with a singular blockchain solution, but that's just not realistic.

The third issue is the sheer unpredictability of moving physical cargos from place to place. As nearly every commodity trader can tell you, there is a lot of potential for things to go wrong: truck demurrage due to a regional bottleneck, a stevedore strike at a port, a political and/or currency crisis, a hurricane closing down a refinery or rail line, a bankruptcy of a player in the middle of the chain, etc.

Fourth, there is the problem of human nature in the actual trading of a physical commodity. Just because a transaction has been recorded in the blockchain doesn't guarantee human performance. Suppose Mike the miller discovers an alternative, less expensive source for the grain he has agreed to buy from Bob the farmer. He may decide to walk away from his existing obligation, even if it is on the blockchain. In another instance, Bob may enter into an agreement to deliver an organic cargo of grains, then switch out the actual, physical cargo for cheaper inorganic grains. True, Bob can't tamper with the chain, but he can tamper with the product. In other words, the chain cannot enforce authenticity of physical supply.

One Link at a Time

In the long run, I am bullish on the theoretical value of blockchain, and I laud those attempting to apply this technology. But I've witnessed these industry roadblocks firsthand. When I launched PanXchange in 2011, I envisioned all the benefits that electronic trading technology could bring to the commodity space. What I did not envision was just how difficult it is to persuade players across a supply chain to put down their phones and adopt a new technology. We have succeeded, but our "ask" is relatively low-risk and low-cost, compared to a technology solution that requires buy-in from ALL industry participants to work.

What has worked at PanXchange is taking a narrow approach to solve a specific industry pain point. Our in-depth industry experience also allows us to tailor our software to each market niche, so that grains traders, for example, can specify exactly the quantities, quality measures and delivery locations that they want. Yes, our trading platform needs acceptance and adoption by a critical mass of industry participants, but we aren't seeking to revolutionize the way everyone trades. (Blockchain salespeople, let me give you a word of advice—stop using that word. No one in this business wants to be "revolutionized.")

Rather than focusing on "revolutionizing," a software solution provider that comes into the commodities space needs to prove to stakeholders in the supply chain that its solution addresses a real pain point, that it's worth the time and money to make the switch, and that the solution provider is going to be around for the long haul. In comparison, based on the presentations and discussions that I have seen up to now, it seems to me that very few if any of the blockchain providers are actually envisioning the true challenges of obtaining an all-in decision to accept blockchain as the definitive decentralized ledger and base technology.

Let me be clear, I do see the potential for blockchain to indeed be transformative. I predict that energy traders will be the first to adopt the blockchain in the physicals space, as they tend to be the most technologically savvy. I predict metals next, then agricultural products last.

While we wait for one industry-wide solution to be launched successfully, let's continue with pilot programs. Start with the points of highest pain, like streamlining those cumbersome bills of lading. Find a reliable blockchain provider or neutral third party that can understand the idiosyncrasies of the physical supply chain and both the opportunities and limitations of the technology. Coordinate the piloting and the implementation with the industry's largest players. Blockchain is ultimately an opt-in solution. Build it to their specifications, and they will come.

Endnote

A version of this article was originally published in *MarketVoice* magazine, a publication of the Future Industry Association.

References

Gramm, P. and H. de Soto, 2018, "How Blockchain Can End Poverty," *The Wall Street Journal*, January 25.

Peck, M., 2017, "Do You Need a Blockchain?", *IEEE Spectrum*, September 29. Accessed via website: https://spectrum.ieee.org/computing/networks/do-you-need-a-blockchain on October 8, 2018.

Author Biography

JULIE LERNER
Chief Executive Officer, PanXchange

Ms. Julie Lerner is the Founder and CEO of PanXchange, a negotiation and trading platform for physical commodities that specializes in bringing liquidity and efficiencies to thin and/or nascent markets. She holds two patents on the system, was selected as a Futures Industry Association Innovator and most recently was selected as an Outstanding Woman in Business by the *Denver Business Journal*.

Ms. Lerner began her career with Cargill International and later became the senior trader for Cargill's Latin American sugar markets where she focused on the development of origination markets with successful financing programs and warehouse and distribution programs. She has also held several positions in trading and business development with companies such as XL Financial (weather derivatives) and Sempra Energy Trading (electricity).

She has deep experience in regional and international agricultural and energy markets. Geographically, her area of expertise covers the U.S., Europe, Latin America and East Africa. She is an advisor to early stage companies and has a 360 degree perspective from entrepreneur to angel investor, and from smallholder farmers to Fortune 100 executives.

Interview with Don Wilson

CEO of DRW; and Co-Founder and Board Member, Digital Asset Holdings

Why did DRW first get involved in cryptocurrencies?

DRW is always looking for new opportunities, and we encourage employees to come forward with interesting ideas. In 2012, several employees were excited about bitcoin and how it might impact the world. Because we couldn't decide what was more important, the distributed ledger technology that underlies bitcoin, or bitcoin itself, we got involved in three different ways: we bought bitcoin; we established a trading desk, which officially became Cumberland in 2014; and we co-founded the distributed ledger technology firm, Digital Asset.

What is DRW's role in cryptocurrency markets? What does Cumberland do?

In 2014, we formally established Cumberland as a bitcoin trading desk, one that is uniquely positioned between the traditional financial industry and the nascent cryptocurrencies space. Since its founding, Cumberland has become one of the world's largest providers of liquidity in cryptocurrencies, with employees in Chicago, London, and Singapore. We leverage our 25 years of experience in traditional financial markets and risk management to provide two-sided, institutional-sized liquidity 24 hours a day, 5 days a week.

How has trading in these markets changed over time and, in particular, over the last year?

DW: These markets have continuously evolved over the years, but 2017 in particular was an important inflection point. There was a shift in the market as people continued to familiarize themselves with cryptocurrencies, but also started putting real capital into the markets. This was evident in the dramatic growth in cryptocurrency valuation we saw over the course of 2017 and marked a new era of exchange adoption as well; CME, CBOE and Nasdaq all announced plans to list bitcoin futures contracts with the former two launching before the close of the year [2017].

What is the significance of the blockchain technology underlying bitcoin?

We recognized the potential of distributed ledger technology [DLT] early on. This technology provides an efficient way of tracking ownership and enables you to do so across multiple organizations securely. We wanted to explore the possibilities of applying this technology to financial processes like clearing and settlement, which led me to co-found Digital Asset [DA]. Digital Asset licenses DLT software to large financial institutions with an initial focus on complex, multi-party post-trade processing. The Australian Securities Exchange recently announced that it intends to replace its equities system with DA's technology. It is managed separately from DRW under Blythe Masters, and I remain a member of the Board.

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

Many people said the rise of cryptocurrency trading is unlike anything they've ever seen. Is this a financial revolution or a bubble?

Looking at the price action over the last year, the market certainly has many characteristics of a bubble – much like we saw with the dot-com era in the 90's. We believe something similar will play out. Many ideas and projects in the marketplace will fail, but that process will give rise to better ideas and projects. Our perspective is that many will go on to make a significant impact on the world.

What does the launch of the bitcoin futures contracts mean for the cryptocurrency trading industry?

The product launches are a natural progression in the maturity of this asset class and are overall very positive for the development of these markets. The futures also reopened the door to an ETF with both the NYSE and CBOE announcing plans to list although the SEC recently slowed down that process. These are products institutional banks are familiar with, which could bring more institutional capital into the markets, furthering the development and maturation of the industry.

Bitcoin is making a lot of headlines, but there are many active cryptocurrencies. What kinds of demand are you seeing for other digital currencies?

The broader interest in decentralized technologies, coupled with the dramatic increase in bitcoin and other token valuations over the last year, definitely led to interest beyond bitcoin. Rather than referring to these instruments as cryptocurrencies, perhaps a better term is cryptoassets, which encompasses both cryptocurrencies as well as tokens issued as a result of an ICO [Initial Coin Offering]. Cumberland is active wherever there is meaningful volume and, today, we trade over 20 cryptoassets. We are continuously adding new tokens to our trades based on demand from our counterparties.

Are the cryptocurrency markets safe and secure? What are some things you do to manage the risks associated with cryptocurrency markets?

While we've certainly seen some vulnerabilities in this new space, bitcoin itself has never been hacked. Where you see the most risk is in the platforms built to facilitate crypto trading and storage, which is why it is important to carefully select the products and exchanges to which you connect. We have a rigorous onboarding process, and we apply our 25 years of experience in risk management, operations and security to our cryptocurrency trading practices. The importance of sound operational practices should not be overlooked.

Wall Street banks have shown some skepticism of cryptocurrency trading, but recently seemed to have softened their stance and a few are opening cryptocurrency trading desks. When will cryptocurrency become more mainstream, and what does that mean for the professional individual trader?

Wall Street has been slowly adopting cryptocurrency over the last year. They have been publishing research on these markets, and they're definitely having conversations about what is or will be their position and strategy on cryptocurrency. We see a dramatic shift in the profile of our counterparties as more institutional capital enters the space, and the institutional banks are developing and introducing their own corporate offerings and establishing trading desks. For the individual trader, that is likely a good thing because there will be a quickening of the pace at which standardized technology is introduced. And if more brokers compete for execution and routing business, that usually leads to price competition and more readily-available research, which benefits the solo trader as well.

Endnote

This interview originally appeared in the Winter 2018 issue of *InsideAdvantage*, a publication of Advantage Futures, http://www.advantagefutures.com.

Biography

DON WILSON
CEO, DRW; and Co-Founder and Board Member, Digital Asset Holdings

Mr. Don Wilson got his start in the derivatives industry in 1989, focusing on capturing opportunities in the markets through technology, research and risk management. He founded principal trading firm, DRW, in 1992 while trading in the Eurodollar options pit at the Chicago Mercantile Exchange. Today, DRW has more than 800 employees at seven global offices and trades in dozens of markets around the world.

Mr. Wilson is also an influential leader in the financial futures industry and is the founder of the FIA Principal Traders Group. He holds an undergraduate degree in Economics from the University of Chicago where he is now a trustee. He is a co-founder and board member of Eris Exchange, as well as Digital Asset Holdings, which leverages distributed ledger technology to improve the settlement of financial instruments.

GLOBAL COMMODITIES

APPLIED RESEARCH DIGEST

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

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

Subscriptions to the *Global Commodity Applied Research Digest* are complimentary because of a generous grant from the CME Group Foundation: http://www.jpmcc-gcard.com/subscribe/.

The Contributing Editor of the *GCARD* may be contacted at hilary.till@ucdenver.edu.

The Winter 2018 *GCARD* cover image is cropped from the following artwork, whose complete image is above: Benton, Thomas Hart (1889-1975) © VAGA, NY. America Today; a) Instruments of Power; b) City Activities with Dance Hall; c) City Activities with Subway; d) Deep South; e) Midwest; f) Changing West; g) Coal; h) Steel; i) City Building; j) Outreaching Hands. Panel a) Instruments of Power. 1930-31. Egg tempera with oil glazing over Permalba on a gesso ground on linen mounted to wood panels with a honeycomb interior, 92 x 160 in. (233.7 x 406.4 cm). The Metropolitan Museum of Art, Gift of AXA Equitable, 2012 (2012.478a-j). THIS IMAGE REQUIRES MMA PERMISSION TO LICENSE ON A CASE-BY-CASE BASIS. Image copyright © The Metropolitan Museum of Art. Image source: Art Resource, NY

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

Physical Address

J.P. Morgan Center for Commodities

University of Colorado Denver Business School

1475 Lawrence Street
Denver, CO 80202

Mailing Address

J.P. Morgan Center for Commodities

University of Colorado Denver Business School

Campus Box 165
P.O. Box 173364
Denver, CO 80217

Web

business.ucdenver.edu/commodities

Contact

Mr. Matthew Fleming
Program Manager
J.P. Morgan Center for Commodities

University of Colorado Denver Business School

matthew.fleming@ucdenver.edu
1.303.315.8019

Business School
UNIVERSITY OF COLORADO DENVER