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IAEE ENERGY FORUM

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PRESIDENT'S MESSAGE

Dear IAEE members,

I am impressed by the diligence of our members during these challenging times with COVID-19 and would like to thank you for your continued support. I truly hope you are all keeping safe. Despite the "no hugs and handshakes", please keep in touch, though, we need to hear from you.

I recall writing in my first message this year that IAEE is like a ship constantly navigating in uncharted open waters. Energy economics combined with environmental issues are redefining the boundaries of social acceptance rather than simply optimizing or minimizing. Well, the economic waves caused by COVID-19 are far bigger than anticipated and it feels as if we have reached the middle of the rogue wave, or tsunami. This is one of the most challenging tests of resilience for humanity. How and when will the world recover, how will the society be back to normal and how will we work in the future are still unknown. One thing is for certain, keeping ideas to yourselves and isolated is not the solution but maintaining an open channel of communications and information exchange for creative solutions is indispensable to tackle this global challenge.

We made the very difficult decisions to postpone most of our planned conferences for 2020. Paris and Austin conferences are postponed from 2020 to 2021 while Tokyo will move to 2022, followed by Riyadh to 2023. Please stay tuned for renewed dates which will be posted on our website. I hope the IAEE community will keep our debate and exchange of ideas active and lively during this hard time until we meet in person. Here is how:

Our association, with its 3800 members worldwide, is best positioned to develop and provide the important service of concentrating information on energy economics. We are the International Association for Energy Economics and we have a role to play. The pandemic is forcing us to search for opportunities and to explore new ways to be effective.

For example, IAEE's response to inform and keep our energy community together has been to produce non-stop webinars and podcasts. As many of you already know, IAEE is already attracting and working with the best academics, practitioners, industrialists and research institutes in the world and many more are invited to join in this effort of providing and sharing information. In the weeks and months ahead IAEE will be working with the best research institutions in the world to collaborate and engage participation from industry/business and governmental organizations in a series of webinars that will keep our energy economics committed well informed and engaged. For you, our members, I encourage you to reach out and be engaged in this lively discussion. Reach out to IAEE's staff at iaee@iaee.org should you wish to organize an IAEE webinar or podcast to reach our membership.

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President's Message (continued)

IAEE is very grateful to our Executive Director, David Williams, for what I would call predetermining the impact of COVID-19 and lining up a special issue of the Energy Forum and how COVID-19 is or will affect the energy industries as they face major demand drops, supply-side shocks, facilities shut downs or even new patterns of electricity demand. The energy industries have been rocked hard. I am grateful to David and his incredible staff for producing this issue on such a short notice.

We have received over 30 articles for this special issue and the replies are overwhelming with the strongest show of interest IAEE has ever had for Energy Forum. I sincerely hope that such a passion will contribute to the creation of wisdom for the energy industries and energy users. And I hope that IAEE will continue to serve our members as an influential community in the field. Before closing, I strongly wish our IAEE family safe during this difficult time of COVID-19 turmoil. In one way or another, we have all been touched by this virus, so please stay safe. In the end, we will come out of this a stronger and better informed society

Yukari Yamashita

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IAEE MISSION STATEMENT

The International Association for Energy Economics is an independent, non-profit, global membership organisation for business, government, academic and other professionals concerned with energy and related issues in the international community. We advance the knowledge, understanding and application of economics across all aspects of energy and foster communication amongst energy concerned professionals.

WE FACILITATE:

- Worldwide information flow and exchange of ideas on energy issues
- High quality research
- Development and education of students and energy professionals

WE ACCOMPLISH THIS THROUGH:

- Providing leading edge publications and electronic media
- Organizing international and regional conferences
- Building networks of energy concerned professionals

NEWSLETTER DISCLAIMER

Editor's Notes

We're most gratified by the response to our call for articles on Covid-19's impact on the energy economy. Nearly 40 articles were received which has resulted in the largest *Energy Forum* ever. Though there obviously is quite a bit of overlap, we've organized these into three groups: First, articles that look at the global impact, second articles more focused on a country or area. And, finally articles focussing on an energy sector.

Michelle Michot Foss explores expectations formed during the previous recession about energy use and draws some inferences for future pathways.

Sam Van Vactor reviews the economic impact of the novel coronavirus as it relates to energy markets. He surveys the impact of Covid-19 on China, Europe and the United States, and analyzes the nature of the virus and how its characteristics have an unusually powerful impact on economic activity. He explains that energy markets have played a key role in identifying and quantifying the economic impact of Covid-19. In turn, energy demand has responded dramatically to the virus and the policy measures put in place to bring it under control.

Cristian Stet draws a parallel between the recent negative prices in the oil and power markets. Additionally, he shows that while negative oil prices are rare events, in power markets, without policy changes or technology developments, those negative prices could become more frequent.

Tilak Doshi notes that Asian governments now face stark trade-offs, as the needs of an immediate, potentially catastrophic health crisis (and its devastating economic fallout) compete with the policy requirements of what the climate industrial complex deems as an equally threatening existential threat of "climate crisis".

Jeff Combs writes that nuclear energy around the world has been negatively affected by COVID-19, although uranium prices have increased notably in recent months as the short-term impact on supply has been greater than demand. The negative effect on electricity demand and nuclear power output is likely to continue into the 2021-2025 period.

Ben McWilliams and Georg Zachmann note that conventional data used to track economic activity are released relatively slowly in comparison with the speed at which economies have responded to the COVID-19 crisis. Electricity data can offer one almost real-time perspective as to how economies have responded. We shed some light on the issue by comparing 2020 consumption

Anupam Dutta, Elie Bouri, Gazi Salah Uddin and Muhammad Yahya examine the heterogeneous and asymmetric impact of crude oil during coronavirus pandemic. Their findings indicate that crude oil responds more asymmetrically, and it may be attributed to demand and supply shock and geopolitical turbulences. Furthermore, the impact significantly increased across all assets with declaration of pandemic from WHO.

Zied Ftiti, Hachmi Ben Ameur and Wael Louhichi review the dynamics of the oil markets during the period of the coronavirus disease and then discuss the prospects of the oil industry in the second half of 2020. Interestingly, we highlight that COVID-19 impacted the oil market based on the output and the stock market channels. Then, we have proposed an outlook for the rest of the year through investigating the prospects for oil demand, oil-supply, oil-consumption and the oil industry.

Pao-Yu Oei, Paola Yanguas Parra, and Christian Hauenstein posit that the COVID-19 pandemic results in a global recession and consequently a drop in fuel prices and global coal demand. This will exacerbate already existing economic challenges of the coal industry and might accelerate global coal phase-out and just transition efforts, depending on the nature of economic recovery strategies.

ARE YOU INTERESTED IN SUBMITTING AN ARTICLE TO *THE ENERGY FORUM*?

The IAEE *Energy Forum* is our members' open publication for submissions. If you have an article you would like to have considered for publication, please email us at iaee@iaee.org

Here's what to do:

- Submit a non-technical article, short in nature (750 - 3000 words) in MS Word format.
- Submit any tables/charts/graphics, etc. in four color, following the following specifications:
  - o Greyscale/Color: 266ppi
  - o Combination (tone and text): 500ppi-900ppi
  - o Monochrome: 900ppi+
- Provide a short (30 word) capsule/abstract that overviews your article.
- Include your full name and professional Affiliation.
- Authors are to submit a description of their work for use on the Association's social media accounts (Twitter account @IA4EE / @USA4EE and LinkedIn

  https://www.linkedin.com/groups/3047782/ and

  https://www.linkedin.com/company/usaee) Please submit 2-3 sentences summarizing your research to iaee@iaee.org.

We hope to receive your submission!

Steven Percy and Bruce Mountain examine electrical demand data to assess the impact of Covid-19 social distancing restrictions in Australia, the United States, New Zealand and Great Britain. They also review changes in mobility and find a strong correlation between mobility trends and aggregate electrical demand. While apparently similar social distancing restrictions in all four countries might have been expected to show up in similar electrical demand and mobility reductions, in fact the picture is very different:

Kenneth Bruninx and Marten Ovaere estimate that COVID-19 decreased carbon emissions from EU ETS sectors by around 38 MtCO2 per month, because of lower emissions from electricity (-9 MtCO2), aviation (-5 MtCO2) and industry (-24 MtCO2). This negative demand shock has limited effect on allowances prices and is largely translated into lower cumulative carbon emissions.

Bangzhu Zhu and Lin Zhang note that the outbreak of coronavirus and its associated quarantine policy have lowered China's carbon emissions by over 184 million tons per month. Such reduction is expected to persist in the long run through structural change of energy mix and the digitalization of its economy.

Michał Narajewski and Florian Ziel note the electricity demand shift effects due to COVID-19 shutdowns in various European countries. They utilize high-dimensional regression techniques to exploit the structural breaks in demand profiles due to the shutdowns. Finally they discuss the findings with respect to coronavirus pandemic progress and regulatory measures of the considered countries.

Giacomo Falchetta and Michel Noussan note that COVID-19 disease containment policies have locked half of the world population at home. The transportation sector is one of the most immediately and starkly hit. We discuss the potential longer-run, structural impacts on transport demand, the behaviour-induced modal shifts, and the implications for sectoral energy demand and environmental externalities.

James Carroll, Kenneth Conway, Alastair Shannon and Eleanor Denny explore how COVID-19 restrictions have influenced electricity demand on the island of Ireland, a single electricity market with different public health restriction dates and intensities. In both areas, more severe "stay at home" restrictions have led to large demand reductions (around 15% reduction in average daily GWh) and changes in the daily load profile, most notably during the morning peak.

David Benatia notes that the enormous reductions in electricity demand caused by containment measures are only moderately disruptive to electricity markets. He draws insights from New York about the consequences of the lockdown.

Abdulrasheed Isah and Gylych Jelilov show that the COVID-19 pandemic has led to supply chain disruptions, declining demand, and falling investments in the Nigerian off-grid renewable energy sector, with adverse implications energy access (SDG7).

Kostas Andriosopoulos, **Kyriaki Kosmidou** and Filippos Ioannidis provide a primary overview of the anticipated consequences of COVID-19 on the Greek economy, by paying special attention to the implications in the Greek energy sector. Aiming to highlight the negative impact they provide a careful comparison between prior and current projections for a list of crucial energy variables.

Bhagavatula Aruna and Acharya H. Rajesh investigate the impact of novel corona virus crisis and various sources of oil price shock on Indian stock market. Using weekly date from January 3rd 2020 to April 10th 2020, our Structural VAR (SVAR-X) model shows that shock arising from total COVID 19 confirmed cases had no negative impact on stock returns. But oil export and speculative demand had significant negative impact on stock returns.

Sylvester Anani Anaba and Olusanya Elisa Olubusoye discuss how the emergence of COVID-19 in Nigeria has altered the economic, social, religious and political landscape of the country, as the shutdown of industries, prohibition of movement of persons as well as unprecedented decline in crude oil prices cramp the economy. The economy which is at the verge of an imminent recession (due to the fall in crude oil price and the lockdown of businesses), has embarked on quantitative easing techniques as well as other palliative measures to cushion the effect of the fall in oil price and the pangs of COVID-19 on the economy. It is believed that Nigeria will overcome the pandemic if, professional guidance from credible institutions (World Health Organization, and Nigerian Center for Disease Control etc.) are strictly followed.

Soni Omontese urges that to support a growing Africa's electricity distribution demand, a multi-energy mutually supported electricity market system, centralized large-scale development bases and sustainable growth strategy must be adopted in achieving cross-border, inter-regional and inter-continental interconnections.

Kakali Mukhopadhyay and Kriti Jain provide a supply and demand impact analysis offor the energy sector in India due to the COVID-19 crisis hitting world markets. They examine the underlying factors influencing the short term and long-term energy security issue for the country and highlight the positive externality generated for the environment.

Daulet Akhmetov and Peter Howie report that with COVID-19, Kazakhstan's power industry has experienced minimal short-term supply-side effects and moderate short-term demand-side effects. Additionally, it will experience substantial long-term impacts because of the reassessment of the role of state, energy security, and climate change. Kazakhstan's experiences provide insights to a power industry operating with new global challenges.

Mamdouh Salameh argues that Saudi Arabia could neither win a price war with Russia nor does it have the production capacity to flood the global oil market with oil. By continuing the price war the Saudis risk bankruptcy of their economy and a destabilization of their country.

Dawud Ansari and Claudia Kemfert present price estimates from simulations of the crude oil market to assess which effect COVID-19 and the initially failed OPEC+ negotiations have had. The numbers allow to reconstruct the price path so far and to discuss which developments can happen from here on.

Lilia García Manrique, Isabel Rodríguez Peña and Mónica Santillán Vera note that the effects of COVID-19 on the Mexican oil sector are important for the economy of the country. Whereas low oil prices affect fiscal revenues, declining gasoline consumption is impacting the demand side of the sector. In this context, oil hedge funds could play a principal role on the recovering of economic activity.

Kentaka Aruga and Honorata Nyga-Lukaszewska use an Auto-Regressive Distributive Lags model to prove that natural gas prices, Jan.,21- March, 30 2020, were COVID-19-immune while WTI and Brent crude oil prices were not

Marula Tsagkari says it's very probable that the current pandemic of coronavirus will radically change the energy sector as demand shrinks and a new era of digitalization lies ahead. Under these new circumstances the integration of distributed energy resources locally and globally with the implementation of demand side management will become priorities in order to deal with the higher penetration of intermittent renewable energy, the unpredictable demand and the need for energy security under future crises scenarios.

Philipp Hauser, C.-P Anke, J. Gutiérrez López, D. Möst, H. Scharf, D. Schönheit, and S. Schreiber describe short-term price trends in energy commodities—oil, gas, coal, CO_2 and electricity—following the onset of the COVID-19 crisis, compared with the 2008 financial crisis, focusing on Germany. Price trends reveal short-run effects, which may persist longer as the COVID-19 crisis itself in case of a recession.

Xiaoming Kan notes that due to the outbreak of the coronavirus, economic activity has been slowed worldwide This has led to a sharp drop in electricity demand and spikes in renewable energy curtailments. This rare phenomenon in the electricity system could offer an opportunity for long-term energy storage to utilize the continuous curtailment in an electricity system with high penetration of renewables.

Fateh Belaid, Adel Ben Youssef, Benjamin Chaio and Khaled Guesm use the latest available data, to provide a coherent picture of the gas market during Q1-2020 in the context of the COVID-19 pandemic. We show that the downward trend in LNG prices for non-residents strengthened but there was no change in the price for residents, signaling incomplete deregulation in the downstream markets.

Bruno Burger and Claudia Kemfert investigate the effects of the corona crisis on power generation in Germany. Compared to the previous year, only a slight reduction in power generation could be observed, especially in March 2020 - the month in which the shutdown in Germany began. In the order of about 3 %. However, a decrease in power generation from coal is evident. This has the following reasons: Due to strong winds, the share of wind power generation has risen disproportionately, which has led to a significant reduction in electricity prices on the stock exchange. Comparatively high CO_2 Emission Allowances prices, together with low exchange electricity prices, reduce the profitability of lignite-fired power plants, so that they are less heavily utilized. In addition, comparatively low gas prices have led to the replacement of coal by gas. In addition, exports of electricity from lignite to neighboring countries become unprofitable, as many neighboring countries can produce electricity more cheaply with their own gas-fired power plants at high CO_2 costs. These effects have led to a substantial reduction in CO_2 emissions, which are likely to be significantly higher than the corona effects induced in other sectors, particularly in the transport sector.

Ranjeeta Mishra and Dina Azhgaliyeva note that Exports of solar PV from China to Japan fell by nearly half in February 2020 due to the COVID-19 outbreak. Although this does not challenge energy supply in Japan due to a small share of solar PV in energy mix, it raises a concern for renewable energy development if import of solar PV continues to be disrupted.

Using hourly metered load and weather data, Dylan Brewer, shows that PJM electricity consumption during the COVID-19 period declined 10.6%, leading to poor-performance of load forecasts. The costs of over-purchasing day-ahead generation were likely low in March 2020 due to mild temperatures; however, the costs may increase as summer approaches.

Eleanor Morrison looks at the uncertain future for independent shale oil producers, in the current low price environment and with scepticism in investor interest to support a cash strapped industry, especially one under a demand side shock, as a result of government response to COVID-19, and a massive accumulation of crude oil in global storage facilities,

Based on the latest available data, But Dedaj, Adel Ben Youssef and Adelina Zeqiri, provide a coherent picture of the gas market during Q1-2020 in the context of the COVID-19 pandemic. They show that the downward trend in LNG prices for non-residents strengthened but there was no change in the price for residents, signaling incomplete deregulation in the downstream markets.

Hongbo Duan, Lianbiao Cui, Lei Zhu, and Xiaobing Zhang, posit that their analysis indicates dramatic negative shocks of the COVID-19 pandemic to energy consumption on both the global and country level, particularly for oil and oil products. The epidemic may also terminate the over-ten-year increasing trend of the world's total CO_2 emissions, despite limited contribution to mitigate global warming.

Energy Markets in the Time of Coronavirus

BY MICHELLE MICHOT FOSS

Across the spectrum of business and economics research and thinking, a grand dissection and diagnosis is taking place. Not just a virus is being placed under the scope. Courtesy of the collapse in oil prices and collapse in energy use attending severe economic dislocation, the excruciating tradeoffs between the humanity of public health and that of economic life are in full view. In this time of coronavirus, we IAEE members, our colleagues and researchers at large need to exercise extreme caution about what we think we are observing and understanding. We've been here before when faced with signature events, and we usually underestimate and misinterpret human adaptability and behaviors.

Backdrop – Cautionary "Tails"

Let's be clear: prior to emergence of the new coronavirus and COVID-19 pandemic, energy markets already were in various stages of tension. Ample supplies of oil, oil products, natural gas and liquefied natural gas (LNG) were pressuring commodity prices and profit margins. Energy demand was cooling within a context of uncertainty about the global economic outlook. The International Monetary Fund (IMF) attributed the global slowdown in 2018 to disagreements over trade (IMF, 2019) and expected a tepid recovery for 2020-2021 (IMF, 2020). China's real gross domestic product (GDP) clocked in at 6.4 percent, year over year, for the first quarter of 2019. The Chinese economy, in fact, has been growing at a diminishing pace, with a steady decline to about half of the 2010 high. The impact of a weaker Chinese performance weighed on China-dependent economies (Taiwan, Hong Kong, Malaysia, Singapore, Korea, Chile and Australia), which collectively declined about two percent in real GDP growth during the course of about a year. The apparent trend for Chinese-dependent economies led to a conclusion "that the Chinese economic outlook may be a bit more concerning than the official data suggest…with China-dependent economies flashing a warning sign and the struggles in Europe ongoing, a further escalation in the U.S.-China trade dispute could slow global growth to lows not seen since the Great Recession" (Pugliese and Bennenbroek, 2019).

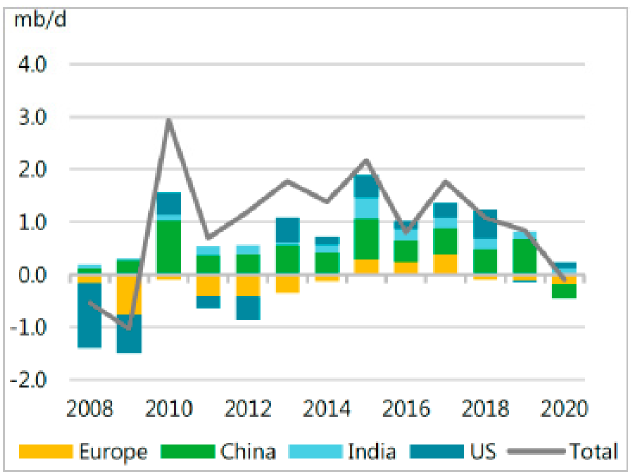

Figure 1. Growth in Global Oil Demand, Year-Year

Source: IEA Monthly Oil Report, March 2020, https://webstore.iea.org/oil-market-report-march-2020.

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See footnotes at end of text.

It is also important to bear in mind that post-2008-2009 recession energy demand growth was not supposed to happen, or at least not in the way, or extent, that it did. Significant events, especially long tail events, induce opinions and judgments about new paradigms that can be biased by the events themselves and how we interpret their impact. Severe recessions, alone or in tandem with other disruptions, can bring out our worst tendencies toward confirmatory, culture and selection bias. A quick tour of two recession effects – housing demand and vehicle ownership and gasoline use – that drove public and private domain outlooks for post-recession energy use demonstrates our hubris, at least for the United States.

- **Housing patterns**: A key post-recession assumption was that the prevalence of younger people continuing to live, or returning to live, in parents' homes signaled the end of home buying in favor of renting, sharing, swapping.

In fact, the National Association of Realtors (NAR) surveys indicate that the main demographic expected to convey most of the recession-driven shifts in behaviors were, in actuality, the largest cohort of

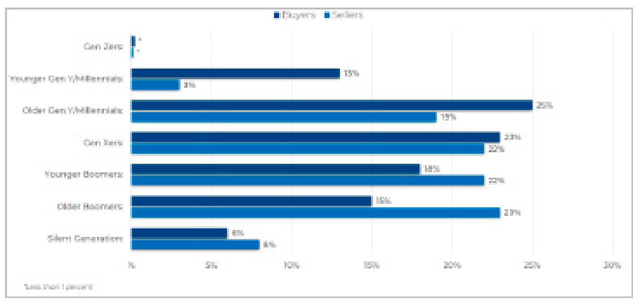

Figure 2. Share of Buyers and Sellers by Generation

Source: 2020 NAR Home Buyer and Seller Generational Trends, https://www.nar.realtor/sites/default/files/documents/2020-generational-trends-report-03-05-2020.pdf. Open source.

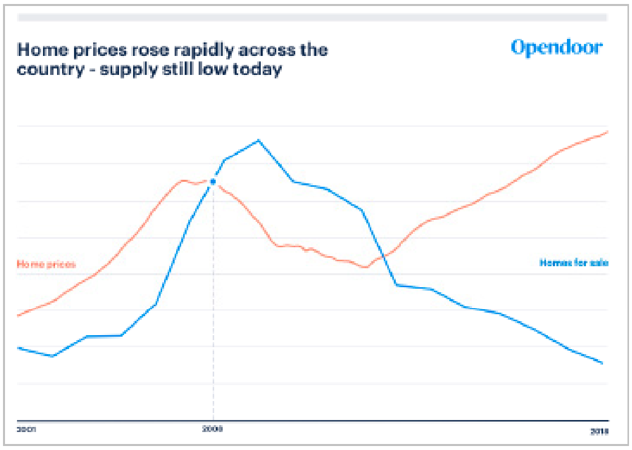

Figure 3. Home Prices and Stock of Homes for Sale

Sources: Opendoor, https://www.opendoor.com/w/guides/2020-housing-market-trends. Based on U.S. Census Bureau, Housing Inventory Estimate, Vacant Housing Units for Sale for the United States, retrieved from FRED. Open source.

home buyers. As measured by the NAR, younger age groups constituted the bulk of both buyers and sellers in 2019. Indeed, younger age groups in 2019 made up the same 79 percent of home buyers (Figure 2) as they did in 2013, the first year of NAR sampling. Home buying patterns reflect a familiar landscape for the U.S., with suburban and exurban single family dwellings comprising the bulk of the market as young families seek out affordability and open space in a tradeoff with work commutes. Indeed, prior to the COVID-19 pandemic, lack of available housing inventory was pushing up prices (Figure 3) and mortgage costs. Borrowing expenses climbed even as interest rates remained low, a relic of federal actions to mitigate economic consequences and spur recovery.

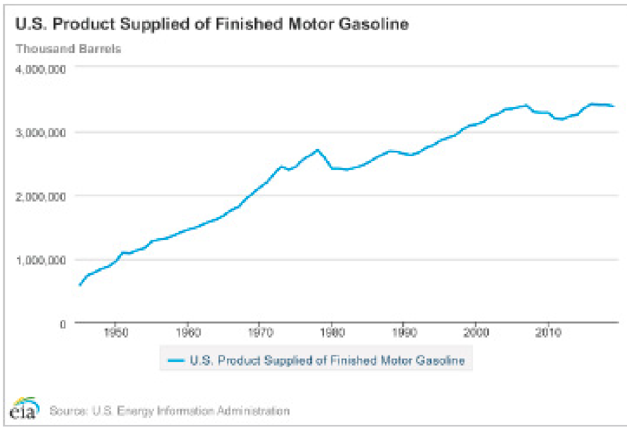

Figure 4. Inferred Demand for Gasoline

Source: EIA, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mgfupus1&f=a. Open source.

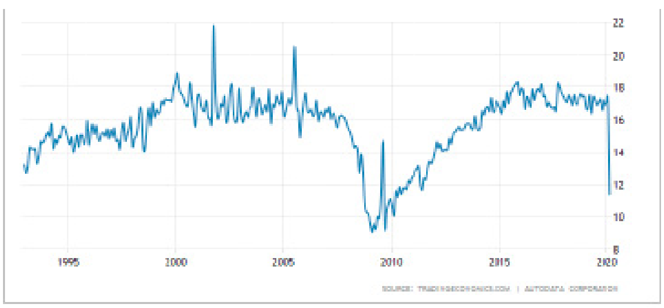

Figure 5. U.S. Total Vehicle Sales

Source: Trading Economics, https://tradingeconomics.com/united-states/total-vehicle-sales. Login may be required.

- **Vehicle sales and gasoline demand:** Pre-recession gasoline consumption represented a "peak demand". Post-recession preferences for communal living along with ride sharing and inability to purchase or lack of interest in purchasing vehicles would combine to reduce gasoline sales and traffic congestion.

After slipping until 2012, U.S. gasoline demand returned to its pre-recession levels. Between 2010 and 2012, crude oil was expensive, a consequence of actions by large producing, exporting countries to pull back on production and seek higher prices and revenues in order to manage political disruptions across the Middle East-North Africa, MENA, region. Leading up to present circumstances, gasoline consumption softened, an outcome of the slower growth trajectory from 2018.

After collapsing sharply during the last recession, total vehicle sales recovered rapidly (Figure 5), preserving U.S. dominance worldwide. Even more interesting, and pertinent for future expectations, has been the pronounced shift in vehicle preferences by customers and automakers (Figure 6). Customers readily switch back to larger vehicles when gasoline prices are more attractive, a reflection of fundamental, and much studied, tastes and preferences. Auto makers have a clear preference to make and sell higher profit margin products. These two sides of the vehicle sales coin represent a rare convergence between producers and customers and present any number of

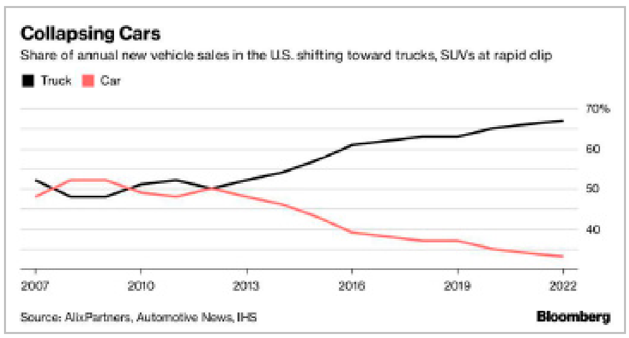

Figure 6. U.S. Vehicle Sales by Type

Source: Bloomberg, https://www.bloomberg.com/news/features/2018-01-16/why-the-american-sedan-is-marked-for-death. Subscription may be required.

profound challenges for the future of electric vehicles or EVs (see Foss and Zoellmer, 2020, for a first pass).

Nor has ride sharing exerted the effect that was widely expected. Widely reported coverage of recent research on urban traffic patterns (see Brown, 2020 for example) suggests that ride sharing habits – with most customers “shunning pooling even though it costs them more” – contribute to congestion. Consumers that replace their vehicles with ride sharing services simply are transferring their demand for transportation fuel. The various research results also point to consequences for mass transit, as ride hail services undermine public transportation options.

Many lessons can be drawn from these and many other vignettes of the previous significant long tail event, a deep, nearly worldwide financial recession brought around by a failure of mortgage risk markets. Will we remain a largely remote, virtual workforce forever? Any number of us are university based and there is plenty of fodder for debate about the future of higher education. Is remote education cheaper? Better? Will pent up demand as we re-engage surprise and swamp expectations about recovery?

As the COVID-19 experience is dissected, conclusions already are being drawn about peak oil demand, permanent shifts in living and work patterns with fundamental alterations in energy use including, perhaps most notably, the “energy transition” itself. In fact, not only are conclusions being drawn, advocacy is intensifying for governments to hasten an energy transition by committing funds to myriad alternative energy expansion programs, including renewable energy, chemical battery storage and electric vehicles. This seems a sure way to waste a precious resource – taxpayer dollars that are needed for the public health emergency response and long term planning for future pandemics as well as recovery from the COVID-19-induced economic collapse. Apart from that consideration, several good reasons exist for discipline in the time of coronavirus. These reflect unrecognized realities embedded in how we have tended to think about “green” energy as well as abundant learnings about how the modern global economy is organized.

Avoiding Potholes and Pitfalls on the Path Forward

First, dealing with COVID-19 has silver linings, and one has been to expose the underbelly of global supply chains. The renewable energy industries, electric vehicles and battery energy storage – the three linchpins of popular responses to energy and environment agendas – fall squarely in that dilemma. Prior to the onset of this pandemic, an important evolution in understanding about China’s dominance in critical aspects of technology and raw materials was happening. This one aspect of the global economy deserves frank and open treatment. Clearly, defining solutions will test political economy institutions and skillsets in the U.S. and abroad.

Chinese photovoltaic manufacturing capacity has undermined not only rival PV makers in Germany, the U.S. elsewhere, as well as within China itself as unutilized capacity has dragged on profitability. The same has been true for batteries and EVs. China controls much of emerging advanced solar and battery technology and intellectual property. Based on analysis of U.S. Geological Survey data and other sources, Chinese dominance of minerals and materials supply chains is clear and inferences for resource competition between China and the U.S. already are being drawn (Gulley, et.al, 2018). Including influence and control in fragile states (see Gbadamosi, 2020 for an excellent and accurate case study), Chinese dominance of raw materials supply chains will test limits of international cooperation. The sphere of influence that is emerging in research and analysis, as we peel the onion on ownership and control of everything from ores to minerals processing and refining to materials components, is not beneficial. Lack of transparency in minerals and metals extraction, production and pricing encumber analysis. As this crisis passes, a priority will be how to reset relationships with China and retool our supply chains to reduce dependence and enable these nascent industries to flourish. We simply cannot proceed with many of our own energy ambitions in the U.S. unless these very tough nuts are cracked.

Second, much work is needed to improve the expansion of renewable energy and, indeed, to “vet” whether that expansion is justified in the first place. Little research has been or is being done on environmental implications ranging from locations of projects and ecosystems impacts to myriad nuisance effects that undermine public acceptance of projects and supporting infrastructure like high voltage transmission. Recycling, disposal and overall end of life management along with an assortment of public safety concerns related to hazardous materials treatment are growing in visibility as distinct challenges. Years of hard and tough work to build markets for electricity, in order to enable more transparency on costs and pricing, are being dismantled to accommodate green energy agendas. This is ironic to the extreme, given that the historic arrangement of regulated electric power, in particular, was blasted by the same interest groups for being too opaque and too heavily controlled by investor owned utilities. From the PGE case study, to the complex meltdown on how best to repair or whether to even keep the PJM capacity market, to the failure to ask basic questions and shine any light on the full gamut of costs associated with integrating intermittent production of electricity into energy systems – there are clear signals that a great deal is lacking in market design. A great deal is lacking even in the capacity to imagine a free and competitive market approach for “new energy”. Rather, proponents continue to devolve to government backing and control.

Third, in truth, no government support for any part of the energy landscape is needed in these times. Investors and the entrepreneurs and projects they support need to find viable business models. Otherwise, many ventures will fail to deliver as promised. This is true regardless of whether it is the stress and strain that will be felt as the shale oil and gas patch is right-sized – and make no mistake, this simply must happen – or the very difficult growing pains as the new energy businesses are pushed through the sorting hat. The harsh reality is that returns on capital to investors have been scarce across all of these ventures. Nor are they anywhere in sight for electric vehicles.

Shale plays, renewable energy projects, battery energy storage, electric vehicles all entail common themes. They require enormous infusions of capital which, in a world of sunk cost fallacy, results in "doubling" and "tripling" down in businesses that are thin margin to begin with. The push to build scale means constant pressure on profitability, exposing businesses and industries to persistent losses. The risk of escalating commitments in the new energy space is made worse by the perception that it is "cheap". Proponents constantly point to low or declining costs for solar, wind and batteries as a main rationale. But those cost curves are nearly entirely driven by Chinese capacity, by Chinese domination of supply chains and by Chinese control and influence over essential raw materials inputs.[3] All of the reactions to these conditions will bend cost curves upward: right-sizing of Chinese capacity, already underway before current events; improving diversity and robustness of supply chains[4], including "reshoring" key manufacturing to the U.S.; reversing the trend of decreasing access to critical minerals resources; the science and technology push to solve persistent shortcomings in performance of batteries, solar and other components.

One thing is for sure – energy systems worldwide will be hallmarked by slack capacity utilization for some time to come. Throwing precious tax dollars at new projects that will only exacerbate supply overhang makes no sense. It is far more important, vital, humane to push our tax dollars toward bolstering the lives of those who face the worst in lost employment and income. Other agendas should simply be parked for the duration.

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[2] Examples, including research by CES fellows, are provided in the presentation by the author during Session 2 of the third annual CES/Baker Botts energy summit, October 2, 2019, https://www.bakerinstitute.org/events/2025/. Information on gaps also is included in the CES film series, https://www.bakerinstitute.org/ces-documentary-series-energy-in-transition/, Energy Transitions segment.

[3] Based on proprietary reports from Bloomberg New Energy Finance, Wood Mackenzie and other sources.

[4] The search for new materials and effective substitutes to solve specific challenges in electrochemical energy storage will push battery costs higher. For example see Hsieh, et.al., 2019.

Recent weeks have seen turbulence in global markets, travel and conferences. In these trying times, staying informed has taken on new challenges as we attempt to balance our professional lives with personal safety considerations. To help you keep in touch, the International Association for Energy Economics has rolled out an extensive program of webinars on topics reaching all facets of energy economics. While recent webinars have focused primarily on the impact of COVID-19 on the energy sector, upcoming virtual presentations are on a wide range of subjects. We invite you to keep an eye on our listing of future webinars at:

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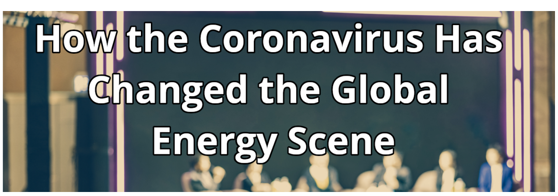

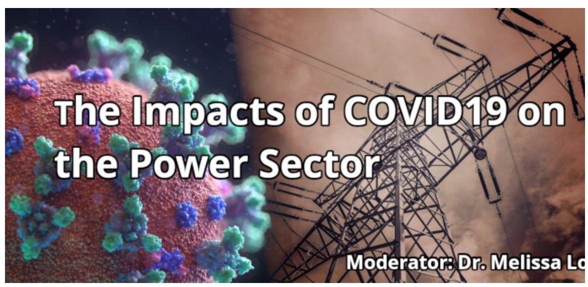

The Impact of Covid-19 on Energy Markets

BY SAM A. VAN VACTOR

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The author wishes to thank Dr. Ronald Ripple and Dr. Marc Vatter for the comments and corrections. Any errors are, of course, the responsibility of the author.

See footnotes at end of text.

Introduction

The World Health Organization (WHO) was informed on December 31, 2019 that a cluster of a coronavirus had broken out in Wuhan China.[1] Further details were provided on January 11th and 12th and WHO began publishing daily reports on January 21st. In three short months since then, the virus has broken out in 185 countries or territories and has plunged the world into a global recession, the first major setback since the Great Recession of 2008.

Energy markets have played an important role by providing early warnings about the economic impact. Once China implemented strict lockdown measures to keep the virus from spreading oil demand turned down. In multiple cases, Chinese companies exercised their "Act of God" contractual clauses to cancel contracts or reduce purchase volumes. The oil market weakened as a consequence, with U.S, oil futures prices falling from over $60 per barrel the first week in January to around $50 the first week in February.

The Stealth Bug

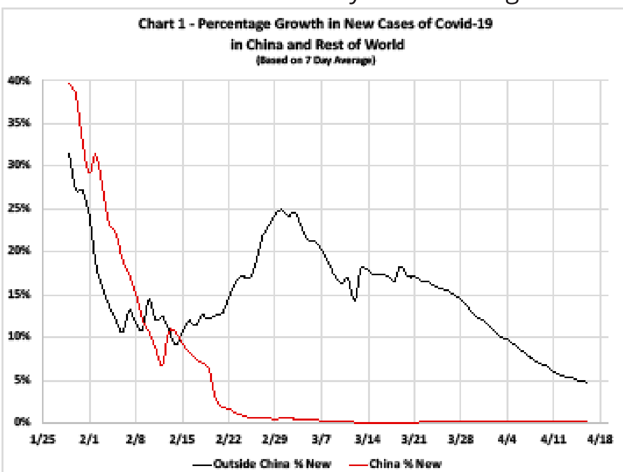
The virus, now known as SARS-CoV-2, has a number of features that explains why it has a substantial impact on economic activity. It has a high infection rate and unlike earlier cases of coronavirus, such as SARS and MERS, this one has a long incubation time – up to 14 days. Writing in the New England Journal of Medicine Bill Gates noted: "Covid-19 is transmitted quite efficiently. The average infected person spreads the disease to two or three others — an exponential rate of increase." [2] These features make containment difficult.

Not only is containment difficult, the virus has a high death rate, especially for those over 60 years of age or with underlying health problems. Bill Gates summed up the problem: "First, it can kill healthy adults in addition to elderly people with existing health problems..."[3] In short, SARS-CoV-2 spreads fear as quickly as it jumps from one host to another.

There is another often overlooked problem. Many infected patients do not exhibit easily identified symptoms or may simply carry the virus without any ill effect, meaning that there is no reliable guide as to who should be quarantined. Moreover, without knowing the percentage of the population that are effectively immune, measuring the rate of spread and likely peak has proven to be a serious challenge. Many of the early forecasts produced alarming results. Most famously, the Imperial College produced a report on March 16, 2020 that estimated that without intervention there would be 510 thousand deaths in Great Britain and 2.2 million deaths in the U.S.[4] These estimates led directly to the adoption of strict "lockdown" measures in Europe, the U.S. and Canada.

Since the release of the Imperial College report forecasts of cases and deaths have dropped sharply – in large measure due to social distancing and other lockdown measures put in place. Most health authorities now rely on the Institute for Health Metrics and Evaluation (IHME) at the University of Washington.[5] The methodologies of the two approaches are quite different. Imperial College based its forecast on data collected on the epidemical characteristics of the disease, infection rates, fatality rates, etc. IHME, however used trend analysis based on the experience in China, Korea, and recently Italy and Spain.[6]

Given that the virus is new, the proportion of the population with immunity or near immunity is unknown. Adding vulnerability and uncertainty to a highly interconnected global economy means that the virus spreads rapidly and causes panic. China and Korea demonstrated early on that the growth



of Covid-19 could be arrested, but at a large cost to economic activity.

Covid-19 Growth Rates

Not since Alexander the Great has an invader made as much progress as the novel coronavirus in conquering foreign lands. Chart 1 illustrates the growth rate of Covid-19 in China and outside China.[7] As the growth of Covid-19 escalated China took action implementing a "lockdown" of the region on January 23rd. The lockdown had the desired impact and within one month the growth rate of new cases fell to 1.3%. As new cases dropped in China, they began a rapid ascent in other parts of the world. Since then, growth rates have dropped to around 5%. However, that growth now has a very large base which means that there are around 100,000 new cases each day.

There are of course many advantages to the globalization of world commerce. It has produced long periods of economic growth and lifted billions of humans from crushing poverty. There are, however, disadvantages too. The same channels of trade that foster low cost manufacturing also provide a framework for the rapid transmission of an infectious disease. The first hot spot outside China was South Korea, where the disease broke out in a religious sect that congregated in large groups. A second hot spot was in the holy city of Qom, Iran, in which there were a number of infrastructure projects financed by China and containing laborers and technicians from China.[8]

In January and February cases in the United States and Europe were primarily limited to individuals coming from China who had been exposed to the disease there. At that time the limited number of cases allowed public health authorities to identify and track the virus's progress.

Tracking and quarantines held down the spread of Covid-19 until a serious outbreak occurred in Italy. The precise origins of the outbreak are still debated, but

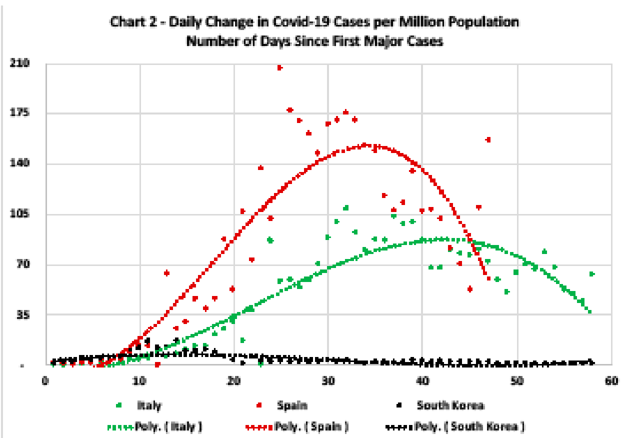


Chart 2 - Daily Change in Covid-19 Cases per Million Population
Number of Days Since First Major Cases

it is well established that Northern Italy has a large number of apparel factories owned and operated by the Chinese.[9] The Chinese communities are tightknit, and some workers do not have legal residency.[10] This combination of features suggests that early cases of Covid-19 would not have been recognized until they spread to the general population. In any case, when Covid-19 cases began to be detected in Italy they accelerated quickly, outpacing Korea in two weeks.

Chart 2 compares the outbreak in South Korea to Spain and Italy. Note that social distancing, tracking, and wide-scale testing held down cases in South Korea. The country had learned from the SARS epidemic and was prepared. Europe was not prepared and the Covid-19 quickly overwhelmed medical facilities.

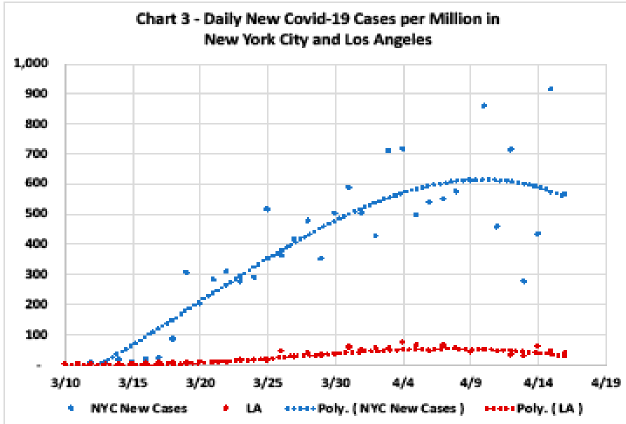


Chart 3 - Daily New Covid-19 Cases per Million in
New York City and Los Angeles

Policy Tradeoffs Between the Economy and Lives Lost

Epidemiologists describe coronavirus outbreaks as clusters. Ordinary flu is sensitive to the season, but generally breaks out across a wide segment of the population at lower infection rates. Covid-19 follows the coronavirus rule in that certain regions seem to have had a more intense outbreak than others. In Europe the most intense clusters so far have been in Italy and Spain. In the United States it has been in New York State and particularly New York City.

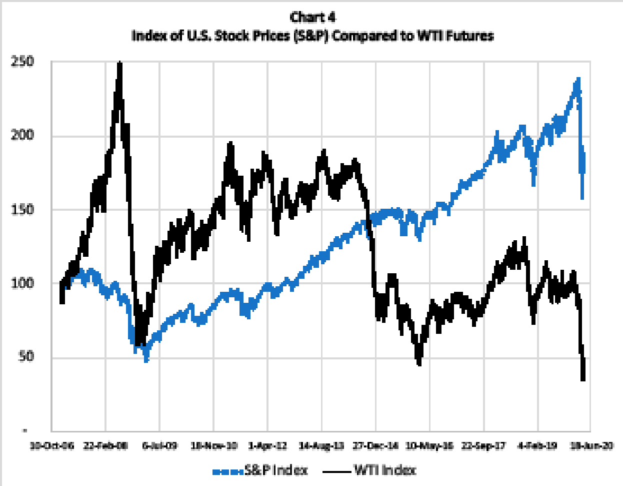
Chart 3 compares the number of Covid-19 cases per capita in Los Angeles to New York City. Both cities pursued social distancing, shut down bars and restaurants, etc. and yet they had vastly different results. Many factors go into determining the intensity of the outbreak: timing of the lockdown, population density, social interactions, variation in cultural habits, etc. Nonetheless, the difference between the two cities is striking.

New York City may hope to be back to normal life fairly soon, but Los Angeles (which adopted lockdown rules earlier in the outbreak) may have to wait to prevent a similar spike. If most residents remain vulnerable, however, some authorities have suggested that lockdown measures may have to be re-introduced. There is precedent for this; there were three different waves to the Spanish Flu between 1918 and 1919.[11] All of this makes predicting the length of lockdowns and subsequent impact on the economy highly problematic.

How Covid-19 Impacts the Economy

Dislocations caused by supply chain disruptions, shifting consumer preferences, and the outright banning of many economic interactions will cause unpredictable shifts in the economy. These shifts, in turn, will impact cash flow and the ability of some companies to service their debt. Put another way, the dislocations caused by Covid-19 could morph into another financial crisis. Large banks are already setting aside reserves in order to cover expected loan losses.

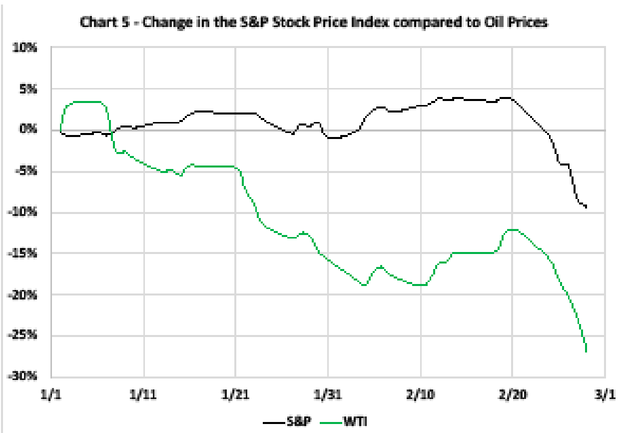
To offset the economic impact most governments



have announced a massive infusion of economic support – outright cash payments, grants, loans, increased unemployment compensation, job guarantees, etc. The problem with these programs is that the broad sprinkling of cash may not reach regions and sectors that have been most damaged.

Energy as a Leading Indicator

To provide some perspective it is worth reviewing how financial and commodity markets changed leading



up to and following the 2008 Great Recession. Chart 4 illustrates the longer-term relationship between oil and stock prices.[12] Oil prices are often a leading indicator of stock market prices. Following the recession oil and stock prices moved together until the summer of 2014. However, the rapid development of U.S. shale oil and other new oil supplies severed the relationship.

In times past, coal miners used to take caged canaries into the mine while they were working. The canaries gave advanced warning about explosive gases or carbon monoxide that would endanger the miners. Analysts have sometimes viewed oil and commodity markets as barometers for the global economy. Although much of the trading is in the futures market, there is enough activity tied to physical flow of commodities to provide some insight into forthcoming economic activity. Buyers have to fix orders well in advance of actual consumption. If orders are canceled or cutback it puts downward pressure on commodity prices. All of this happens in real time. In contrast, stock prices are based mainly on estimated earnings lagged several months. It can be argued that commodity markets are the canary in the coalmine, presupposing changes in the real economy.

Chart 5 illustrates the change in oil prices as compared to the change in the S&P stock price index in the critical period of the Covid-19 breakout. U.S. crude oil prices dropped over 15% through February 10th due to concern about China's oil demand. At the same time stock prices were unmoved by what appeared to be a localized virus. However, over the weekend of February 22, South Korea had a major outbreak with the number of cases rising from 204 on Friday to 833 the following Monday. At that point the S&P index also began to decline as markets recognized that Covid-19 could spread beyond China.

Table 1 (Year on Year Change)

Date	Crude Oil and Product Stocks	Total Product Supplied	Gasoline Supplied	Kerosene Supplied	Diesel Supplied
Jan-20	1.2%	-3.3%	-3.6%	-0.5%	-5.8%
Feb-20	1.2%	-1.9%	1.0%	-7.5%	-6.8%
Mar-20	1.8%	-2.1%	-5.6%	-15.2%	-4.9%
Apr-20	4.2%	-30.0%	-46.4%	-64.5%	-13.3%

Source: EIA

The Dramatic Drop in Oil Demand

After mid-March oil prices and stock prices parted ways. This was due in part to the failure of Russia to agree to a production cut set by the OPEC cartel on March 6th. Two days later Saudi Arabia launched a price war by ramping up production and announcing additional discounts to indexed prices. The resulting supply shock threatened to flood the market with even more oil.

Ultimately, the price of crude oil is determined by what consumers are willing to pay for petroleum products, particularly motor fuels. The market reached a low point on March 23rd, when the price of wholesale gasoline actually fell to 49 cents per gallon, over $2 per barrel below the price of West Texas Intermediate (WTI) crude oil. The Saudi supply shock would have an impact on the order of 2 or 3% of total supply, well short of the Covid-19 panic, which has reduced global oil demand by up to 35%, in the short run.

Table 1 summarizes weekly petroleum supply data published by EIA. Overall stocks have increased as crude oil backed up in pipelines and storage filled up. Compared to April last year, crude oil and petroleum product stocks have increased 4.2%. In the first two weeks of April overall products supplied declined 30.0%, gasoline was down 46.4% and jet fuel was down 64.5%.

Impact on U.S. Shale (tight) Oil Production

The dispute between Saudi Arabia and Russia centered partly around shale oil development in the U.S. Russia wanted prices to drop in order to stifle U.S. shale oil production. Saudi Arabia's interests were more complex and for the short term they focused on increasing market share, at the expense of Russian sales to Western Europe.

Unlike conventional crude oil fields shale oil has a relatively high short-term price elasticity. Conventional fields decline gradually over many years. Shale oil, however, has a steep decline rate. Over one-half of the oil produced from a shale oil well will be produced in the first year. In order to keep production rates up, companies have to constantly drill and complete wells

Following the dispute between Saudi Arabia and Russia, U.S. crude oil prices fell to under $20 per barrel on the futures exchange. Field prices for oil fell much further, given the infrastructure problems of transport and storage. On April 15th Plains All American Pipeline posted prices for crude oils in the field that ranged from $3.50 for high sulfur oil in Texas to $16.50 for domestic sweet at Cushing Oklahoma.[13] Eagle Ford Light in Texas (a major shale oil play) was posted at $16.25 per barrel.

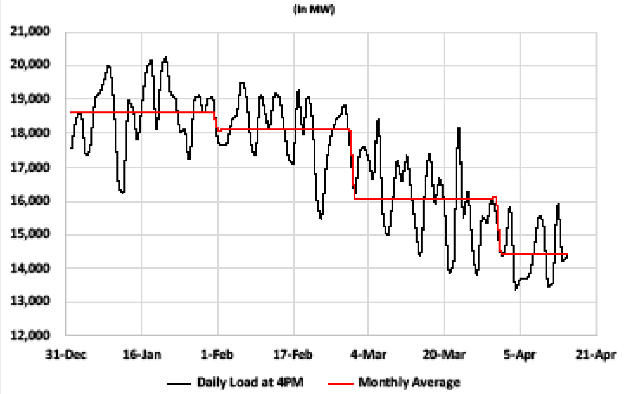
A smilar price collapse happened after the summer of 2014, but it took several years for the market to bottom out. In February 2016, futures prices reached $26.21 per barrel, with corresponding deductions for field prices. The bottom did not last long, however, and shale oil production continued to increase. There is of course a lag between price changes and shale oil production. It took nearly a whole year for the weaker market to impact production. By December 2016 shale oil production had stabilized and then doubled output in four years, reaching 8.2 million barrels per day (mbpd,) producing heartburn from Riyadh to Moscow.

Table 2 - Impact of Covid-19 on U.S. Retail Sales 2020

Activity	Change February to March	March	February
Clothing & clothing accessories stores	-50.48%	$11,088	$22,389
Furniture & home furn. stores	-26.81%	$7,337	$10,025
Food services & drinking places	-26.50%	$48,559	$66,066
Motor vehicle & parts dealers	-25.59%	$79,302	$106,571
Sporting goods, hobby, musical instrument, & book stores	-23.31%	$4,982	$6,496
Gasoline stations	-17.15%	$35,326	$42,641
Electronics & appliance stores	-15.13%	$6,870	$8,095
Miscellaneous store retailers	-14.30%	$10,299	$12,018
Retail & food services	-8.73%	$483,066	$529,262
Building material & garden eq. & supplies dealers	1.35%	$33,829	$33,380
Nonstore retailers	3.11%	$68,787	$66,712
Health & personal care stores	4.27%	$30,807	$29,546
General merchandise stores	6.40%	$63,781	$59,946
Food & beverage stores	25.58%	$82,099	$65,377

Source: US Census Bureau

Chart 7 - NYISO Daily Load at 4PM
(In MW)



Various estimates suggest that tight oil production will drop quickly, by up to 2 mbpd at the end of this year. Many independent oil producers were in a weak financial condition before the price war and it had become increasingly difficult to finance new production. In the four-year period when production doubled, productivity increased by around 15% per year.[14] Similar productivity increases are likely to continue. The industry has been plagued in recent years by difficult infrastructure shortages. Modest production cuts will reduce the pressure on infrastructure and improve field prices relative to New York and London benchmarks. In short, the shale oil industry is here to stay and there is no price level acceptable to Russia or Saudi Arabia that will eliminate it.

Electricity Load as an Indicator of Economic Growth

The key economic indicators that influence markets and policy makers are calculated after-the-fact. For example, the Bureau of Economic Analysis did not release calculations of 4th quarter GDP for the U.S. until March 26th.[15] By the time data for the first and second quarters of 2020 are available, lockdowns may be over. Other data, however, can provide some insight into economic activity. Table 2 from the U.S. Census Bureau provides a snapshot of the impact of the virus and associated lockdowns on a variety of retail sales. It should come as no surprise that food and beverage stores had a whopping large increase and that clothing got pummeled. Overall, retails sales were down 8.7%, despite the fact that most states did not implement stay-at-home orders until mid-March or later.

As described earlier, lower crude oil sales first signaled pending economic problems. Likewise, electricity consumption tends to mirror changes in economic output. In countries lacking reliable data on GDP, electric load growth has been used as a means to approximate economic growth.[16] In response to Covid-19, Governor Cuomo of New York issued a statewide stay-at-home order on March 22nd. Electricity load had already dropped before the order, and it fell further soon afterward. Chart 7 illustrates the impact based on average weekly load at 4PM each day.[17] During the first two weeks in April the load averaged 22.5% less than during the month of January. These figures are comparable to the reduction in petroleum products supplied, confirming that U.S. GDP will decline significantly in the first half of 2020.

Conclusion

It is unlikely that the economy will return to normal before a vaccine or an effective medication for those taken ill is developed. Energy markets have been particularly stung by the virus because they provide essential services for manufacturing, transportation, and many of the engines of economic growth. Most of the energy demand collapse is temporary, and once lockdowns lift, commuters will return to the roads, rails and air[18]ways. However, there has also been a great deal of energy demand destruction. Companies are learning how to pull work together from remote locations, exotic vacations are not a necessity, a great deal of business can be conducted by video conferencing, no one has to eat out every night, and the shift eliminating many jobs by automation and artificial intelligence has been accelerated.

Chart Sources

Charts 1, 2, 3: JHU

Charts 4 and 5: EIA, CNBC

Chart 6: EIA

Footnotes

[1] Vatter, M., Van Vactor, S., and Coburn, T., "Impact of Shale Oil on the Global Market," paper presented at IAEE International Conference, Montreal, June 2019.

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[8] Case data are quite erratic, particularly in the early stages of the outbreak. This chart was prepared by calculating a 7-day running average of the number of cases and calculating a growth rate based on the rolling average. [9]

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Oil Prices in Negative Territory? In Power Markets Frequent Negative Prices Could Become the Norm

BY CRISTIAN STET

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See footnotes at end of text.

Introduction

With most world economies having imposed different forms of lockdowns or isolation measures, it is by now clear that Covid-19 has a great impact on most of us. As industries must rethink their strategies, millions of people are adapting to working from home, and others are pushed into temporary unemployment. Some industries, such as hospitality or outdoor leisure industries, are being hit very hard as supply of such services was curtailed through legislative imposed measures. For other industries, the decreased societal mobility led to expansion opportunities, as their products act in these moments as substitutes for the curtailed products. The first examples that tend to come to our minds are the so-called stay-at-home companies, such as Amazon, Zoom or Netflix. Since there are less possibilities to go to malls, online shopping is increasing. Since in person meetings are restricted, the usage of online videoconferencing tools is growing. Since cinemas are closed, online movie streaming platforms are attracting more clients. While not identical, another example comes from the oil industry. Because of the Covid-19 restrictions put in place around the world, over the past weeks we observed unprecedented low oil demand levels. As a result, as oil refineries are operating at a lower capacity, traders had to look for places to store the excess oil that is being produced. This situation led to oil storage companies suddenly seeing the values of their stocks and products rise substantially. On the other side of the table, oil producers struggle to place their products in this overflooded market.

Through a spiraling of events, the current oil market arrived into a situation where market participants were trapped with positions that they could not physically comply with. As a result, the prices of WTI crude oil futures for delivery in May 2020 settled for a few hours way below the level of 0 USD/barrel.

Negative oil prices explained through what we know from power markets

In this exceptional event, the main question that arises is why this situation occurred? The answer to this question represents a story of flexibility and storage. Though storage providers are benefiting from the current oil market state, their upside potential is limited since the world's storage capacity is close to being reached. Next, storage expansion is a costly and lengthy process. The other obvious alternative for stabilizing the market is reducing supply. Leaving aside the geopolitical and strategic thinking hurdles that affect the supply reduction equation, a major reason for which oil companies are not willing to cut production is that such a process is extremely costly. In some cases, closing a well could permanently damage it. Thus, such an action can lead to losses far greater than the profitability damage incurred by temporarily selling the produced oil output at a price below the marginal cost or even below 0. What this ultimately means, is that at least some of the oil producers are inflexible as they do not have the technical or economical ability to quickly ramp up or down production when needed.

The second question that arises is: can we see negative oil prices again? As long as storage possibilities are limited or extremely costly, supply and demand is relatively inflexible, and a big oversupply is temporarily present, there are good reasons to makes us believe that negative oil prices might reappear. To better understand this answer, we should look towards power markets. In electricity, price patterns that we see in oil markets over a timeframe of decades, can be spotted within only one day. Electricity is a commodity that is often traded in an environment similar to the actual oil markets. This happens because power storage is extremely costly and largely insufficient, demand for power is relatively inflexible, and various power markets are being catered to a certain extent by inflexible producers. Storage in power markets is still in early phases as economically feasible utility scale batteries are still generally out of reach. Power demand has been historically inflexible, and it is only recently that new ideas got more traction, ideas such as shifting the consumption or transforming the excess power produced into other products such as hydrogen. In addition to the inflexibility of demand, same as for the oil market, some producers are not flexible enough to be able to ramp up or down production in a fast and economically efficient way when a sudden change in demand occurs. In such a market, a high demand drop often leads to temporary oversupply as the inflexible suppliers are not able to act fast enough to restore the balance. All these factors create the favorable climate for negative prices to occur. Therefore, while negative oil prices are regarded as black swan events, in power markets such negative prices appear frequently.

With the characteristics presented above, power markets serve as the perfect example for at least partially explaining what oil markets are going through in the present months. What makes the two markets more comparable nowadays is that at the moment, in both markets storage options are limited. This is not the case in normal market conditions. Storage in oil markets is able to provide in normal market conditions a relatively cost-efficient solution to short term changes in the balance between demand and supply. Most of the times, storage availability makes it easier for the oil market to smooth the prices and to avoid extremes. Consequently, while negative oil prices might appear again, they are unlikely to appear over the next few years.

What about negative prices in power markets?

Because of the constant absence of enough storage capacity or demand-supply flexibility, power markets already for years experienced negative prices. Those prices do not seem to go away anytime soon. On the contrary, we should be aware that the frequency of negative power prices could grow significantly in the future if markets remain inflexible. While the blame for the inflexibility of the power markets is often given to conventional producers, such as coal generators, that have technical difficulties to quickly ramp up or down production, this is only part of the story. The other main reason for the inflexibility of the power markets is embedded in the business model of the variable renewable sources, namely wind and solar power plants. Variable renewables have close to 0 marginal costs, making them the cheapest producer of electricity when bidding in power markets. Moreover, on top of having very low operational costs most, wind and solar power installations are further propelled by various subsidy schemes, from feed-in tariffs to green certificates. These aspects lead wind and solar renewables to being profitable even when power prices are negative. Essentially, we could almost say that subsidized renewables have a negative marginal cost. Thus, in some markets there is a strong incentive for variable renewable producers to generate the maximum output possible even when prices get negative. This is in line with what energy economics literature predicts: on average, the more wind and solar output we have in a power market the lower the prices we observe.

In addition to their cost structure, another aspect that favorizes the occurrence of extreme low prices is the dependency of wind and solar output on weather conditions. The variability in production output of these two technologies create supply shocks on daily basis, in addition to demand shocks that we are already used with. Therefore, with the higher integration of variable renewable sources in power markets, as the average level of electricity prices gets lowered, the supply-demand imbalances lead more often to extreme low prices than to extreme high prices. In a study conducted together with my colleagues Ronald Huisman and Evangelos Kyritsis[1], by analyzing empirically the German day-ahead market, the biggest power market in Europe and one having a high share of wind and solar installed, we prove that higher levels of the share of variable renewable supply lead to less frequent extreme high prices and more frequent extreme low, sometimes even negative prices. Additionally, in another work developed along with Ronald Huisman[2] we show for the same market that the higher the level of variable renewables the more extreme the low power price spikes appear to be.

Covid-19 lesson on negative prices in power markets

Based on the academic evidence, as the share of variable renewables is set to increase in many power markets, if there is not enough flexibility in critical moments, negative prices will occur more and more frequently. Besides learning this from academic studies, the same lesson can be drawn from current Covid-19 situation. With the temporary closure of businesses in the recent weeks, demand for power fell by even over 20% in some European markets. At the same time, wind and solar operational capacity remains at the same levels. This leads to power markets suddenly operating into a much higher share of variable renewables environment. Thus, we have in front of our eyes a unique experiment: the current situation fundamentally represents what power markets would be in the future if the only thing we change is adding more wind and solar output to power markets.

The results? Continuing with the example of the German day-ahead power market, while for the period 23rd March – 22nd of April 2019 the average share of generated wind and solar production was 30%, for the same timeframe in 2020, the last month, the average share of variable renewables grew to 44%, with recorded values of over 60% for certain days within the past month. While a small part of this wind and solar share increase is due to some new installations that came into the market over the past year, the main factors that temporarily increased the share of variable renewables is the lower demand and favorable weather conditions. With an increased wind and solar output, over the last month there were various moments when the German day-ahead prices fell below or close to –80 EUR/MWh. While we already observed in the past such negative prices on this market, the frequency of the negative prices increased. In total, over the past month, 49 hours were settled on the German day-ahead market with negative prices. Over the same period in 2019, only 10 hours traded with negative prices, and, on average, the monthly number of negative prices in 2019 was under 18 hours/month. Similar increase in the numbers of hours with negative settled prices can be observed across most European markets during the past few weeks. In some markets the negative prices appeared as a result of an increased share in variable renewable output. In some other markets, negative prices were propagated through cross border transactions. One example comes from the Hungarian day-ahead power market where in the last month already 9 hours were traded in negative territory, compared to only 1 such observation for the entire year of 2019. Similar situation can be found in The Netherlands, with 37 hours traded with negative power prices in the past month as opposed to 5 such observations for the entire year of 2019. Another example from earlier this year comes from the Swedish and Finish power markets as they documented for the first time in history negative prices The list can go on, but the message is clear: in a world of subsidized and prioritized variable renewable supply, without adequate flexibility in place, we will have to get used to more frequent negative prices.

Is there anything else we can conclude?

While power prices are not driven only by the output of variable renewable sources, the final cleared prices being formed based on a multitude of fundamentals, we know already from academic literature and practice that wind and solar output changes the electricity price patterns. The behavior of the European power markets in recent times teaches us that, while striving to integrate more renewables in our markets, we should also make sure that power markets are flexible enough to cope with it. Working on improving storage or demand shifting possibilities is one welcomed, a path that is extensively considered. In addition to that, we should also reconsider the way we operate wind and solar plants and decide if the current subsidy schemes, which served their purpose in the past, are still a viable solution for the future. Moreover, while prioritizing variable renewable supply for dispatch is desirable from an environmental point of view, we should also consider if the flexibility benefits of temporarily and locally curtailing the production from renewables outweigh the costs. Ultimately, extreme prices are not desirable for a functional market. Even if from a consumer perspective low or negative power prices are appealing, if power prices fall too low, they will affect not only the conventional polluting producers but also the investments in new installations of renewable supply, as the attractivity of such investments will decrease. Thus, without a change in policy or technological developments, the transition to a carbon free power market will continue to be tied up to public financial aid.

Footnotes

[1] R., Huisman, E., Kyritsis and C., Stet, 2020. Fat Tails due to Variable Renewables and Insufficient Flexibility.

[2] R., Huisman and C., Stet, 2020. The stronger variable renewable supply impact on extreme day-ahead electricity prices.

Covid-19 And Climate Change: Asia's Policy Choices In The Age Of 'Crisis'

BY TILAK DOSHI

The Asian continent spans a vast geographical area. The novel coronavirus emerged in the eastern part – Wuhan, China – and quickly spread to other countries within a couple of months after first reported cases in December.[1] In Asia's western reaches lie the Maldives, long the posterchild of the international climate change establishment which claims, among other things, that the low-lying tourist islands will be submerged as sea-levels rapidly rise with global warming.[2]

Asian governments now face stark trade-offs, as the needs of an immediate, potentially catastrophic health crisis (and its devastating economic fallout) compete with the policy requirements of what the climate industrial complex deems as an equally threatening existential threat of "climate crisis".[3] As Asian policymakers grapple with immediate measures to handle the epidemic with unprecedented lockdowns of entire cities, provinces or even nationwide, they are no doubt keenly observing how their counterparts in the US and Europe are meeting this common challenge. Few if any of the developments in the West will inspire confidence.

The U.S. Congress passed a $2.2 trillion coronavirus relief package which was signed by President Trump last Friday. But this was only after a week of partisan delay caused by the Democrats' insistence on provisions that had little to do with handling the pandemic. Speaker of the House Nancy Pelosi failed in her bid to incorporate climate change provisions in the stimulus bill. In an expansive wish list, the bill included new tax credits for solar and wind energy and emissions standards for airlines by 2025 as part of the party's Green New Deal ambitions.[4]

To be fair, Ms Pelosi is not alone in the cynical attempt to "never let a good crisis go to waste". Across the pond, European Commission President Ursula von der Leyen doubled down on the EU's climate commitment with a €1 trillion Green Deal.[5] She presented the European Climate Law on March 4th, when the Wuhan virus was fast metastasizing into a global pandemic. The law, which would legally bind EU members to net zero carbon dioxide emissions by 2050, was presented by Ms. von Leyen while flanked by none other than teenage Green icon Greta Thunberg. In an odd twist of logic, Frans Timmermans, leading the Commission's work on the European Green Deal, said that the focus on the coronavirus pandemic "showed the need for climate laws". [6] In the revolutionary language of the EC's Green Deal, all policy matters including coronavirus-related public health and economic stimulus legislation would have to be in line with net zero emissions by mid-century.

International bureaucrats have echoed these calls for stiffening the resolve to pursue climate legislation in the face of the mounting Covid-19 crisis. Fatih Birol, head of the International Energy Agency and a prominent climate policy advocate, advised world leaders and heads of financial institutions to exploit the "historic opportunity" presented by the pandemic and "use the current situation to step up our ambition to tackle climate change."[7] Christiana Figueres, former head of UN Framework Convention on Climate Change and architect of the Paris Agreement, tweeted "Well put @IEABirol...We have a massive crisis = opportunity on our hands. We cannot afford to waste it. Recovery must be green." [8]

Not surprisingly, these incessant calls for governments to finance ever-greater ambitions in emission reductions while the coronavirus pandemic imposes immediate hardships on afflicted countries have led to strong objections. One EU diplomat put it baldly: "We simply don't have the money to do everything." Another said that "Maybe it will be less on Green Deal but more on trying to restart the economies...We cannot just continue with the plans and programmes we had so far. They were developed for a world without coronavirus."[9]

Poland's government, never a fan of the EU's Green ambitions, stated that the country — heavily dependent on coal-fired power generation — would not be able to achieve the EU's climate change goals because of the impact of the coronavirus epidemic on its economy.[10] Holland, a richer European economy at the forefront of the EU's climate ambitions, cited the toll of the virus pandemic in announcing that no new measures will be taken to reduce emissions.[11] Bavaria's Chief Minister called on the federal government to provide relief from the deepening pandemic crisis by suspending carbon taxes and renewable energy subsidies which have made electricity rates in Germany among the world's highest. [12]

For policymakers around the world, the Covid-19 pandemic has provided a reality check, a painful reminder of what a real existential crisis looks and feels like. Inevitably, the global focus on the Covid-19 pandemic has come at the expense of attention paid to hypothetical model-based notions of a future "climate emergency". Perhaps the most consequential price

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See references at end of text.

to be paid on the trade-off between the two policy objectives will be in Asia, the world's most populous continent.

Japan, the world's third largest economy and one of its richest, is the first major signatory of the Paris Agreement to submit updated plans on cutting emissions in preparation for the now-postponed November 2020 Glasgow meeting. It was widely criticised by climate campaigners for failing to intensify emission targets as called for by the 'spirit' of the Paris Agreement.[13] Many an Asian policymaker will see Japan's refusal to submit tighter emissions reduction targets in view of the Covid-19 pandemic as pragmatic and necessary.

China, the world's second largest economy and its biggest emitter of greenhouse gases, plans a fiscal stimulus worth hundreds of billions of dollars to restore economic growth.[14] Given the country's economic structure as the 'workshop of the world', this implies the resuscitation of carbon-intensive activity, ranging from coal to oil, natural gas, petrochemicals, plastics, and refineries — and reviving jobs for the multitudes who work in automobiles, aviation, shipping, utilities, construction, agriculture, manufacturing and utilities. Hence it is no surprise that China plans to postpone automobile emission standards and "save the industry" post-Covid-19.[15]

In the emerging countries of Asia, among the impoverished masses without access to reliable and affordable electricity systems needed to power modern medical care, the lethality of the Covid-19 pandemic can only be imagined at this stage. Vast swaths of Asia lack clean water, sanitation systems, and refrigeration for vaccines, let alone respirators and personal protective equipment for front line medical workers. These cannot be provided at scale by solar or windmill farms. The strictures against fossil fuels, as part of the liturgy of climate change belief, are egregious to the extreme when the real and immediate challenge of coping with Covid-19 faces each and every Asian today.

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COVID-19 and Nuclear Energy

BY JEFF COMBS

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The COVID-19 pandemic has impacted nuclear power and the nuclear fuel industry on both the supply and demand side. In the short term, the impact is greatest on the supply side for uranium, as various mines and nuclear fuel cycle facilities are suspending operations due to health concerns. As a result, as of this writing, the uranium price has increased 33 % from its lowest point registered in mid-March this year and has broken the $30 level for the first time since 2016.

Production cutbacks in uranium have a positive impact on price since demand for uranium has not suffered to nearly the extent as the demand for oil. These cutbacks have occurred in several major uranium mining countries – Kazakhstan, Canada, and Namibia – which account for about two-thirds of world uranium production. How long these cutbacks will last is unknown, but they are likely to continue into the summer and result in a drawdown of available inventories.

Demand for nuclear power and the resulting demand for nuclear fuel has also been impacted, but not nearly to the same extent as oil due to the nature of underlying demand for electricity versus oil. The Energy Information Administration estimates that the demand for electricity in the United States will decline by 3% this year. In France, where nearly 75% of electrical generation comes from nuclear energy, electricity demand is projected to be down 15-20%. As a result, France's EDF has already downgraded its nuclear power generation outlook for both 2020 and 2021 by 8-12% less than its pre-pandemic forecasts.

In addition, the supply of nuclear power, which also impacts the demand for nuclear fuel, has been affected by COVID-19. In this regard, nuclear plants are experiencing extended outages related to the health of workers. A number of nuclear utilities around the world have announced some sort of impact from COVID-19. However, this supply-side impact is expected to be minor over the short term.

Reactor construction schedules have also been impacted due to COVID-19 issues. In China, which accounts for much of the world's new reactor build, some new reactor projects have been halted temporarily but have now restarted. Reactor construction in the United States, France, the United Arab Emirates, Bangladesh, and the United Kingdom have also been negatively impacted. These delays are a function of the reduction of staff at the construction sites and disruptions in the supply chain.

The delay in reactor construction along with the drop in electricity demand will likely negatively affect nuclear power output in the 2021-2025 period, but the extent of the impact is uncertain at present. In China, which has the largest new reactor construction program, economic growth has suffered as a result of the COVID-19 pandemic (due to developments both inside and outside of China) and thus the need for new electricity generation has slowed. It should not be surprising if the decline in economic growth and associated electricity demand in China extends into 2021, as is projected in France, or perhaps beyond.

A key question is the extent to which COVID-19 will influence how policymakers and others look at nuclear power in the future. One lesson of the pandemic is the downside of waiting to implement changes that can address existential problems in the future. In this regard, if climate change is seen as a huge problem on the horizon, there might be an acceleration of nuclear power plant construction to reduce carbon output. Also, the calculus of risk will likely change; one might be willing to tolerate more risk now to avoid having to confront a far greater risk in the future. This could impact how quickly new reactor designs, which are slated to be more economical and safer, are licensed.

Another fallout from COVID-19 will be a desire to diversify supply chains. This will require accelerated economic development in different regions of the world. Access to adequate electricity will be necessary to accommodate this development, and here small and micro nuclear reactors could play an important role as they would be a better fit for many existing grid systems in less developed regions. This potential need could accelerate the development of smaller, advanced reactors, some of which can be built in factories and transported to their final location.

While the results of any accelerated new reactor build would not be seen in the 2021-2025 period, this period will likely be pivotal for the future of nuclear power as the world adapts to a post-COVID-19 environment. If this environment results in the desire for a much-reduced carbon economy, the expansion of nuclear energy could be notable, as it has the potential to play a major role in this transformation.

Electricity Consumption as a Near Real-time Indicator of COVID-19 Economic Effects

BY BEN MCWILLIAMS AND GEORG ZACHMANN

The COVID-19 health crisis and associated lockdowns are clearly having huge economic impacts. Economic activity has been impacted by both demand and supply reductions. Understanding the relative size of such effects is important for policymakers at the national and European level. However, real time trackers of economic activity are hard to come by. GDP figures are typically released only on a monthly or quarterly basis.

Data on national electricity consumption are released daily and can be manipulated to offer some indication as to the size of the ongoing economic disruption in different countries. This is possible because so much modern economic activity has become reliant on the use of electricity. Significant drops in average daily electricity consumption of around 20% occur on weekends and during public holidays when large parts of the economy are shut down.

Using electricity demand data from available European countries as well as Russian regions, we are able to track how consumption has evolved in response to national lockdown measures. Results generally confirm the expected effects. Effects are quite dramatic in Italy, with some of the harshest lockdown measures, whilst effects are almost negligible in Sweden where lockdown measures have not seriously been implemented.

Methodology

Electricity demand will be affected in myriad ways by the crisis. Industrial demand will decrease due to the forced or voluntary closure of many manufacturing plants. Moreover, shops, restaurants, bars, pubs, and other operations within the services sector have been forced to shut down.

On the other hand, there may be a slight increase in household electricity demand as a result of people spending more time at home. For example, an increase in internet usage from video calling might contribute to increased consumption.

	2020	2019
Week 1	2nd March - 6th March	4th March - 8th March
Week 2	9th March - 13th March	11th March - 15th March
Week 3	16th March - 20th March	18th March - 22nd March
Week 4	23rd March - 27th March	25th March - 29th March
Week 5	30th March - 3rd April	1st April - 5th April
Week 6	6th April - 10th April	8th April - 12th April
Week 7	13th April - 17th April	15th April - 19th April

Table 1: Comparison of weeks

We are interested in better understanding the effects on economic activity. We focus on peak-hour consumption (08:00-18:00) because this is when most economic activity would normally take place. We consider only working days, ignoring weekends and removing any public holidays from the sample. The few resulting missing values are interpolated over.

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We calculate an average consumption across peak hours. We compare this directly with the corresponding day from 2019 to compute daily ratios. For weekly ratios, average peak consumption across each week in 2020 is compared with the corresponding week in 2019 as shown in table 1.

Confounding factors

Other underlying factors influence demand, in addition to COVID-19. Temperature is perhaps the most important. In particular countries, a significant share of space and water heating is electric and one would expect significant fluctuations depending on daily temperatures. We therefore adjust average peak values from each year by the temperature differential.

In order to understand the relative effects of temperature on peak consumption for each country we ran bivariate regression analyses. We took a sample of winter months from the past two years and regressed average daily temperatures on average peak consumption. This provided us with the slope coefficients listed in Table A1 (appendix). These coefficients were used to adjust values from 2020, depending on the temperature differential with the corresponding day from 2019.

One complication that arises from our data is that Entso-e provides the actual total load on the transmission grid. This means that any generation produced within distribution grids or "behind-the-meter" appears in the data as a reduction in demand. Given that we compare 2020 to 2019, the difference this makes should be largely removed. However, for certain countries, there may have been slight increases in distributed generation year-on-year. This would exert a small downward pressure on presented ratios. The effect may be larger on particularly sunny or windy days when solar panels and wind turbines within distribution grids produce a larger share of overall consumption. Slight disturbances to day-to-day variation may thus result. It is more unlikely that weekly reported figures would be influenced by this.

Data sources

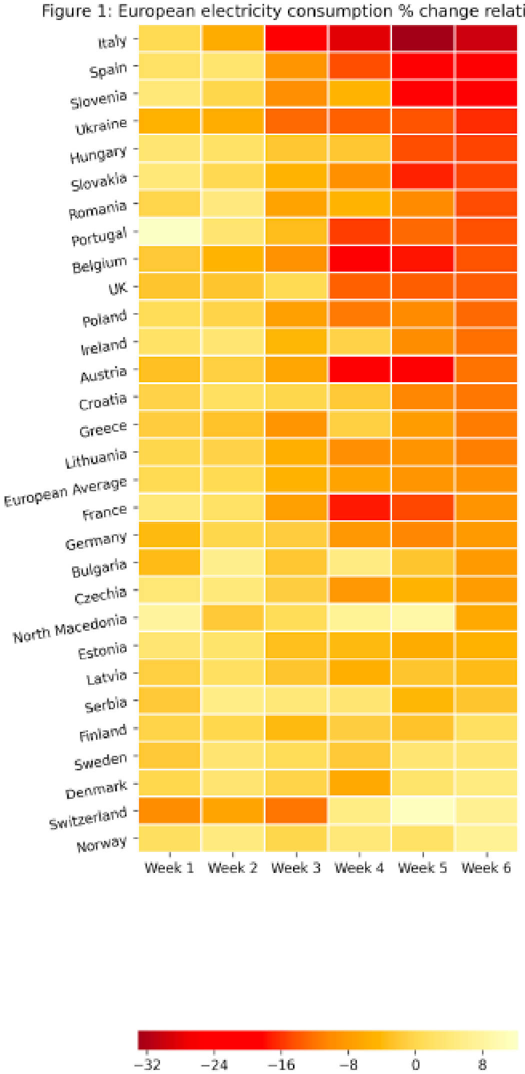
We take data on 'actual total load' from the Entso-e transparency platform. We take temperature measurements from the National Centers for Environmental Information, selecting the best covered weather station from each national capital. For Russia, both data on load and temperature are taken from The Unified Energy System of Russia. We also take data on national public holidays from available online sources, and these dates are excluded from national analysis.

Results

Europe

Figure1 provides an overview of how electricity consumption has evolved in Europe since 2nd March 2020. Each coloured cell represents consumption in a week from 2020 relative to consumption from 2019 once adjusted for temperature. The range of differences are from -32% change to a positive 8%

Figure 1: European electricity consumption % change relative to 2019



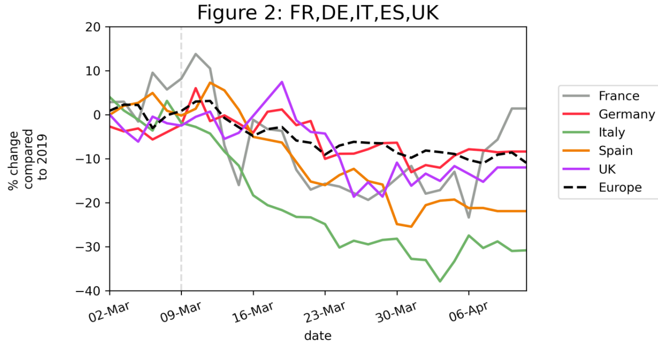
change. The figure is ordered according to the largest relative reduction in demand during the most recent week, as of publication, week 6.

Figures 2-4 show the daily evolution of electricity demand for selected European countries. Common features in all graphs are the dashed line on the 9th March representing when President Conte of Italy imposed a national quarantine. Other European countries reacted at different speeds and imposed lockdowns at later dates. Everything before the dashed line can be assumed to be pre any lockdown measures. The 'Europe' plot represents average electricity consumption across all considered countries.

There are certain unusual spikes in countries' demand. This can be explained by some of the factors outlined above: for example, on certain (sunny and windy) days the share of consumption may shift significantly between the distribution and transmission grid. Moreover, our method of temperature adjustment improves accuracy but is not perfect. It may cause some overcompensation of demand, e.g., France on the 8th and 9th March (our temperature adjustment likely overcompensates for the fact that the temperature was much hotter on those days than in 2019). Such fluctuations are why we believe weekly averages are a better indicator of how large effects are. Using electricity demand to track daily effects is certainly appealing but it appears more robust to do so on a weekly basis. Nonetheless, daily data provide an insight into how countries immediately reacted to their lockdown measures.

Figure 2 shows demand for France, Germany,

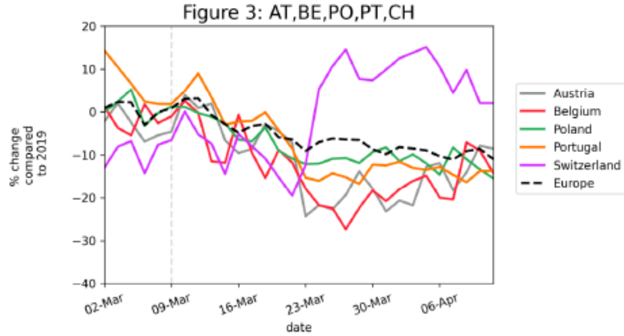
Figure 2: FR,DE,IT,ES,UK



Italy, Spain, and the UK. Italian electricity demand has been the worst affected, consistently 30% below 2019 levels. Spanish demand has trended to around a 20% reduction since lockdown measures. Lockdown measures in the UK were introduced between 20th and 23rd March. Before those dates, demand had not responded much at all to the COVID-19 crisis. Post 22nd March, UK demand reacted sharply dropping to levels of 15% below 2019.

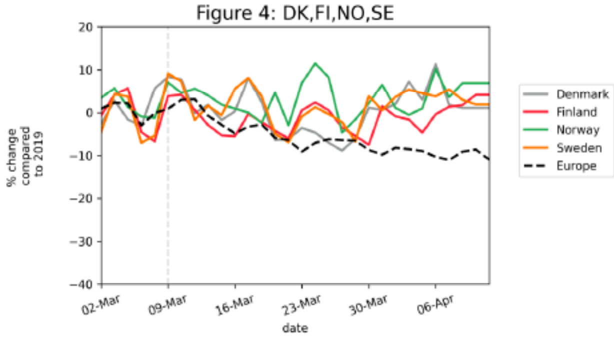
Figure 3 shows Austria, Belgium, Poland, Portugal, and Switzerland. The first four all follow a standard

Figure 3: AT,BE,PO,PT,CH



response with demand decreasing in line with lockdown measures. Switzerland is an unusual case were demand does not appear to have been negatively impacted by the COVID-19 crisis.

One interesting development has been the lack of any reduction in the Nordic countries of Denmark, Finland, Norway, and Sweden as shown in figure 4.

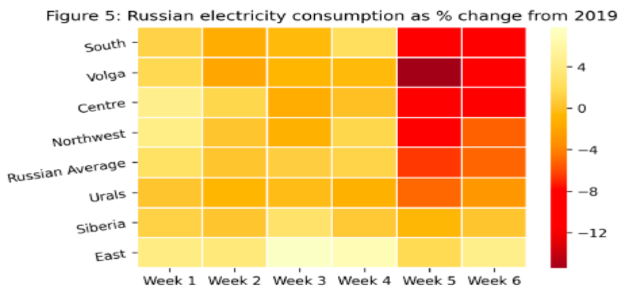


Sweden has been a relative outlier among European countries without announcing any severe lockdown measures. However, the other Nordic countries have not experienced any significant reductions in electricity demand in spite of implementing their own lockdown measures.

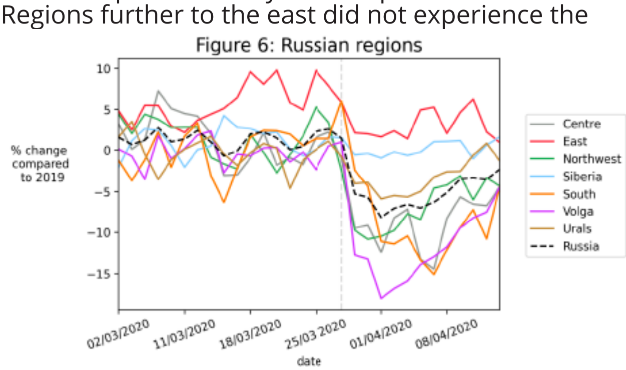
The overall European line represented in all figures shows that European demand has been approximately 10% below 2019 from 16-March until the end of our current sample.

Russia

Figure 5 focuses upon Russia regions. Russia



declared lockdown slightly later than European countries. On the evening of March 29th, lockdown measures were announced for Moscow which were then gradually extended to the rest of Russia. Initially, a 'non-working' week had been announced but measures were quickly scaled up. The following Monday 30th corresponds to week 5 in our data. The immediate effects are very clear. In western Russian regions, there was a drop in electricity consumption of around 10%. Regions further to the east did not experience the



same shock.

Figure 6 provides a closer look at Russian regions on a daily basis. The shaded line on 27/03/2020 shows the last day before lockdown measures were imposed. There is an immediate reaction in all regions. Demand in the Volga region appears to drop the most by about 15% before gradually recovering over the next week. The next most affected region appears to have been the South region. The black shaded line shows the average reduction across all Russian regions. Interestingly, many Russian regions appear to be increasing consumption again after the initial sharp drop. However, it is perhaps too soon to read too much into this.

Concluding remarks

In many European countries, as well as Russian regions, electricity demand has reacted sharply to the announcement of COVID-19 lockdown measures. There are certainly difficulties associated with a comparison of electricity consumption between years. Yet, the indicator is certainly revealing and can be utilised by policymakers in order to better understand the size of economic shocks which countries are currently facing. Over the coming weeks and months, electricity demand will continue to play a key role in estimating economic disruption and particularly how well economies are able to recover and move out of lockdown mode.

Appendix

Country	Change in peak consumption (MW) for a 1 degree Celsius increase	Country	Change in peak consumption (MW) for a 1 degree Celsius increase
Austria	-104	Portugal	-88
Belgium	-103	Romania	-82
Bulgaria	-112	Serbia	-85
Croatia	-28	Slovakia	-33
Czechia	-104	Slovenia	-17
Denmark	-55	Spain	-350
Estonia	-18	Sweden	-383
Finland	-176	Switzerland	-80
France	-1728	Ukraine	-281
Germany	-331	UK	-610
Greece	-154		
Hungary	-54	Russian Regions	
Ireland	-29	Centre	-276
Italy	-308	East	-59
Latvia	-10	Northwest	-131
Lithuania	-15	Siberia	-180
North Macedonia**	-13	South	-207
Norway	-305	Urals	-170
Poland	-185	Volga	-88

Table A1: Change in peak consumption for a 1 degree Celsius increase estimated by country

Impact of COVID-19 on Global Energy Markets

BY ANUPAM DUTTA, ELIE BOURI, GAZI SALAH UDDIN AND MUHAMMAD YAHYA

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1. Introduction

The unprecedented time of panic and astronomical uncertainty from the COVID-19 outbreak in January -March 2020 has led to a massive sell-off in financial markets and a huge spike in market volatility levels. The COVID-19 risk factors are severely damaging global economic activities, and evidence suggests that recession is already in place[1]. Notably, there has been a sharp decline in the crude oil market that is often seen as a barometer of economic activity. As shown in Fig. 1, the Brent crude price fell from over $50 in January 2020 to $22.58 a barrel at the end of March 2020, its lowest level since November 2002. In the interim, the price of U.S. West Texas Intermediate (WTI) also fell below $20 a barrel, dropping to lowest level for 18 years. A similar pattern is witnessed in Dubai crude oil prices. Furthermore, during the February -March 2020 period, the crude oil implied volatility index (OVX) depicted in Fig.2, reached their highest level since its inception by the Chicago Board Options Exchange (CBOE). Likewise, the prices of the Energy Select Sector SPDR Fund (XLE) decreased sharply.

Table 1: Summary Statistics of daily returns

	January 2019-November 2019				December 2019-March 2020			
	WTI	Brent	Dubai	XLE ETF	WTI	Brent	Dubai	XLE ETF
Mean	0.083	0.102	0.053	0.011	-1.169	-1.393	-1.082	-0.821
Std. Dev.	2.183	2.122	2.113	1.204	7.057	5.402	4.657	4.743
Skewness	0.526	0.363	0.531	-0.185	-2.199	-2.061	-3.276	-1.451
Kurtosis	9.666	6.084	13.156	3.514	15.67	9.032	23.056	9.732
JB test	451.68***	99.55***	1034.18***	3.98	644.67***	191.26***	1595.26***	192.6***

Notes: This table reports summary statistics for daily returns of the three crude oil indices and the energy ETF. JB refers to the Jarque-Bera test. *, ** and * indicate 1%, 5% and 10% levels of significant respectively.**

Table 2: Correlation matrix of daily returns

	January 2019-November 2019				December 2019-March 2020			
	WTI	Brent	Dubai	XLE ETF	WTI	Brent	Dubai	XLE ETF
WTI	1				1			
Brent	0.69*** (0.00)	1			0.63*** (0.00)	1		
Dubai	0.69*** (0.00)	0.70*** (0.00)	1		0.70*** (0.00)	0.81*** (0.00)	1	
XLE ETF	0.61*** (0.00)	0.57*** (0.00)	0.59*** (0.00)	1	0.66*** (0.00)	0.79*** (0.00)	0.78*** (0.00)	1

Notes: This table reports the pairwise Pearson correlation coefficients for daily returns on the three crude oil indices and the energy ETF. *p*-values are provided in parentheses. *, ** and * indicate 1%, 5% and 10% levels of significant respectively.**

While the academic literature considers the response of the crude oil market to news events related to macroeconomic, OPEC announcements, terrorist attacks, or other extreme events such as wars and natural disasters (e.g., Zhang et al., 2009; Lin and Tamvakis, 2010; Demirer and Kutan, 2010; Brandt and Gao, 2019) , there is scarce evidence on the effects of rare disaster risks not related to macroeconomic, geopolitical, or war events on the energy markets.

In this paper, we extend the above line of studies and the resulting research gap by examining the impact of COVID-19 on energy market returns. To this end, we use an event study framework that has been a standard approach in the academic literature (e.g., Lin and Tamvakis, 2010; Demirer and Kutan, 2010; Kim et al., 2019). Specifically, we seek to answer the following questions: To what extent has the COVID-19 outbreak pushed the international crude oil prices lower? Is the negative effect of the COVID-19 outbreak on crude oil prices similar or dissimilar across the various international crude oil benchmarks (WTI, Brent, Dubai). What are the effects of the COVID-19 outbreak on the XLE index? Answering these questions is important for the sake of investors and policymakers given previous evidence that episodic events such as the 9/11 attacks and the Iraq War become the main driving factors for oil returns from 2000 to 2004 (Fan and Xu, 2011).

For comparison purposes, three different oil markets are considered in our empirical analysis: WTI, Brent and Dubai. Due to global economic integration, news events travel and transmit quickly from one financial market to another. Hence, taking diverse markets into consideration would help understand whether COVID-19 impacts crude oil markets globally or locally.

Table 3: Cumulative abnormal returns (CARs) following COVID-19 events

Markets\Event windows	2-day CAR	3-day CAR	4-day CAR	5-day CAR	6-day CAR
Panel A: Event 1					
WTI	-0.069**	-0.075***	-0.089***	-0.110***	-0.112***
	(0.029)	(0.026)	(0.022)	(0.019)	(0.019)
Brent	-0.028***	-0.031***	-0.021*	-0.054***	-0.042**
	(0.001)	(0.006)	(0.011)	(0.016)	(0.017)
Dubai	-0.066***	-0.071***	-0.079***	-0.098***	-0.104***
	(0.024)	(0.023)	(0.021)	(0.018)	(0.017)
XLE	-0.025**	-0.021*	-0.030***	-0.033***	-0.036***
	(0.009)	(0.012)	(0.010)	(0.009)	(0.008)
Panel B: Event 2					
WTI	-0.030***	-0.035***	-0.065***	-0.040**	-0.035*
	(0.008)	(0.009)	(0.009)	(0.019)	(0.018)
Brent	-0.019	-0.082**	-0.079**	-0.047	-0.045
	(0.022)	(0.034)	(0.032)	(0.036)	(0.032)
Dubai	-0.042***	-0.091***	-0.099***	-0.058*	-0.063**
	(0.011)	(0.018)	(0.019)	(0.033)	(0.030)
XLE	-0.037	-0.057***	-0.060***	-0.030	-0.013
	(0.028)	(0.019)	(0.018)	(0.026)	(0.023)
Panel C: Event 3					
WTI	-0.054***	-0.038	-0.116***	-0.162***	-0.427***
	(0.003)	(0.025)	(0.038)	(0.034)	(0.099)
Brent	-0.150***	-0.118	-0.267***	-0.274***	-0.485***
	(0.051)	(0.072)	(0.080)	(0.074)	(0.092)
Dubai	-0.096***	-0.035	-0.128*	-0.142**	-0.214***
	(0.014)	(0.064)	(0.066)	(0.058)	(0.055)
XLE	-0.147***	-0.038	-0.164	-0.137	-0.272***
	(0.056)	(0.112)	(0.107)	(0.099)	(0.098)

Notes: This table reports the cumulative abnormal returns (CARs) for international crude oil markets following several events linked to COVID-19. These events take place on (1) January 7, 2020: Chinese government confirms that they have identified a novel coronavirus; (2) January 30, 2020: WHO declares this new virus to be a "Public Health Emergency of International Concern"; and (3) March 11, 2020: WHO announces COVID-19 to be a Pandemic. To measure the CARs following these events, we consider 5 different event windows including (0,+1), (0,+2), (0,+3), (0,+4) and (0,+5). Standard errors are provided in parentheses. *, ** and * indicate 1%, 5% and 10% levels of significant respectively.**

Employing a standard event study method, our findings suggest that the new contagious disease, which has spread globally during the last few months, has substantial negative effects on international crude oil markets. While the negative effect is consistent across the three international crude oil prices used, its magnitude exhibits some differences. The effect is also significantly negative for the energy ETF, but is generally weaker, suggesting some heterogeneity in the negative response of the energy markets to the COVID-19 outbreak.

In the rest of the paper, we first provide an overview of materials and methods in section 2. Section 3 provides the empirical findings and section 4 concludes the study.

2. Materials and methods

We investigate the effect of three events related to COVID-19 on crude oil returns and energy ETF returns. The events take place on (1) January 7, 2020: Chinese government confirms that they have identified a novel coronavirus; (2) January 30, 2020: WHO declares this new virus to be a "Public Health Emergency of International Concern"; and (3) March 11, 2020: WHO announces COVID-19 to be a pandemic. Accordingly, we choose a sample period covering the aforesaid periods, which makes our sample period to span December 1, 2019 - March 31, 2020.

In line with Chen and Siems (2004), we employ a standard event study method[2] in which the abnormal returns are computed as follows:

$$AR_{it} = R_{it} - \overline{R_j} \quad (1)$$

where AR_{it} refers to the abnormal (or excess) return for oil (energy ETF) index i at time t, R_{it} denotes the actual observed rate of return for oil (energy ETF) index i at time t, and $\overline{R_j}$ indicates the mean of oil (energy ETF) index i's daily returns in the (-30, -11) estimation period. We calculate $\overline{R_j}$ as follows:

$$\overline{R_j} = 1/20 \ \Sigma_t R_{it} \ ; t = -30,\ldots\ldots,-11 \quad (2)$$

Within this framework, t = 0 indicates the event date. The mean adjusted returns model is estimated over 20 days, from t = -30 to t = -11 relative to the event date. Several event windows have been used to capture the impact of COVID-19 outbreak on oil (energy ETF) returns. They include (0,+1), (0,+2), (0,+3), (0,+4) and (0,+5). For each of these event windows, we calculate the cumulative average abnormal returns (CARs). We compute the statistical significance of the event period abnormal returns using the test statistics proposed by Brown and Warner (1985).

While the choice of the event window may appear somewhat arbitrary, it is chosen with the aim of capturing the effects of COVID-19 events and keep them separate from the effects of other potential events. Furthermore, crude oil prices are efficient and absorb information quickly, hence need a relatively short event window[3].

3. Empirical findings

Table 1 provides several summary statistics for daily returns, while considering two sample periods. As expected, higher negative returns and higher volatilities are observed over the sample period December 1, 2019 - March 31, 2020 compared to the period January 1, 2019 - November 30, 2019. Table 2 also shows higher correlation values across the three international oil markets during the period December 1, 2019 - March 31, 2020, which reflects the COVID-19 risk factor underlying the oil markets.

Table 3 exhibits the results of the event study analysis (Panel A, Panel B, and Panel C show the results for event (1), event (2) and event (3), respectively). The results suggest that the COVID-19 outbreak has a strong negative effect on international crude oil returns, given all the cumulative abnormal returns have a minus sign. These results indicate a downturn in international crude oil markets following the coronavirus disease.

Note that among the events considered, the last event related to the WHO's declaration that COVID-19 is pandemic has higher impacts on crude oil returns than the remaining events. For example, the magnitude of 6-day CARs for Brent market amounts to 4.2%, 4.5% and 48.5% for event 1, event 2 and event 3, respectively. For other crude oil markets, we find similar negative effect, but its magnitude is dissimilar. Notably, Table 1 reveals that of the three oil markets, WTI is more influenced by this new virus compared to Brent and Dubai. Almost all the CARs based on WTI index are statistically significant at conventional levels. Furthermore, the magnitude of these CARs is also higher than that of Brent and Dubai in most of the cases.

Moving to the energy ETF, our analysis shows that all the events studied have experienced negative CARs. However, this effect is generally weaker compared to the oil markets, suggesting some sort of heterogeneity in the negative response of the energy markets to the COVID-19 outbreak. Moreover, like the crude oil markets, the event announcing COVID-19 to be a pandemic has more influence on the XLE index returns than the remaining events.

These results are quite different when compared to important economic and war events. In fact, the magnitude of the effect of the COVID-19 is much stronger than that reported for the case of terror attacks (Orbaneja et al., 2018), FOMC announcements (Demirer and Kutan, 2010), or the global financial crisis (Ji and Guo 2015).

To sum up, there is a significant drop in global crude oil prices following the events linked to COVID-19 and this impact is the highest when this novel coronavirus disease is declared to be a pandemic. We find that the informational content of a COVID-19 outbreak is large enough to influence investors' perceptions. Accordingly, with the advent and amplification of the COVID-19 outbreak, future demand of crude oil is in doubt and traders add a huge uncertainty or "recession premium" to the prices.

4. Conclusions

We provide strong evidence that the COVID-19 outbreak exerts substantial negative effects on energy markets. More specifically, international crude oil markets are negatively influenced by this novel virus as reflected by the sharp negative downturn in energy markets following this global pandemic. Given the importance of growing pandemic of COVID-19, our findings have important implications for policymakers and investors holding assets in international energy markets. In order to maintain the stability in the energy market, it is important for global stakeholders (U.S., Russia, OPEC and etc.) to maintain the collaboration in order to minimize the geo-political uncertainty. Given that the value of an option is an increasing function of the volatility of the underlying asset, future studies can investigate if an option's prices are sensitive to the

COVID-19 crisis.

Footnotes

1 In the U.S., estimates from St. Louis Fed indicates that the COVID-19 economic freeze could cost around 47 million jobs and skyrocket the unemployment rate to 32% (https://www.cnbc.com/2020/03/30/coronavirus-job-losses-could-total-47-million-unemployment-rate-of-32percent-fed-says.html).

2 Notably, the event study methodology was first introduced by Fama et al. (1969). It has been applied to the crude oil markets (e.g., Lin and Tamvakis, 2010; Demirer and Kutan, 2010).

3 For example, Wirl and Kujundzic (2004) use around two trading weeks before and after the events. Demirer and Kutan (2010) apply a 10 and 20 days before and after the events.

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New Outlook for Oil Market in the New Post-Coronavirus World

BY ZIED FTITI, HACHMI BEN AMEUR AND WAEL LOUHICHI

Since the beginning of the twentieth century, and particularly within the period of globalization, disease outbreaks have taken different forms and have elicited different reactions as the spread across countries has varied in speed and scope. In 2002–2003, the world experienced the severe acute respiratory syndrome coronavirus (SARS) that spread to more than twenty countries, albeit with a relatively lower number of infections but with a mortality rate of around 8%. The next large-scale contagion was the Middle East respiratory syndrome coronavirus (MERS coronavirus) that was transmitted to 27 countries, with an even lower number of infected cases (around 2460), but with a much higher mortality rate of around 36%. The most recent pandemic of coronavirus disease, known as COVID-19, has new and different characteristics compared to more recent outbreaks; the fast pace with which it has spread around the world, the exponential increase in the number of infected patients, and a relatively high (15%) proportion among them needing respiratory support.

Three months after the emergence of the first few cases in China, COVID-19 has killed over 120,000 people and infected more than 2 million around the world. This pandemic has brought about a significant change worldwide by constraining normal lifestyle, global economic systems, financial markets, and oil markets as well. The main impact of COVID-19 on the oil markets is based on its exposure to both demand and supply shocks at the same time. The oil price, which was $63.05 per barrel on December 30, 2019, fell down to $53.0 on January 21, 2020 (at the time of the Wuhan database creation), and continued this downward trend in the subsequent two months to $21.55 per barrel (as at 21 March 2020). A formal investigation is therefore important to understand what happened during the current health crisis within the context of oil prices, and it is equally as important to discuss the outlook for the oil industry for the rest of the year.

In this note, we aim to understand the dynamics of the oil markets during the period of the coronavirus disease spread and then discuss the prospects of the oil industry in the second half of 2020.

From health crisis to oil crisis

Hamilton's (1983) seminal paper established a relationship between the oil market and the real economy. Theoretically, this relationship is modelled through several channels, such as stock valuation, monetary and fiscal measures, output, and uncertainty channels.[1] We posit that COVID-19 has impacted the real sector as well as the financial market by affecting the output and the stock valuation channels, as the mobility of workers, tourists, trade, and transportation has been affected by this crisis, leading to an overall collapse in demand.

Figure 1 displays the dynamics of oil prices during the coronavirus disease. More interestingly, since the beginning of January 2020, we have observed a downward trend because of a shock in oil demand, caused by COVID-19 and specifically the lockdown in China (January 23, 2020). A second, decreasing episode is observed around February 21, 2020, when Lambardy's cluster is detected, and continues from one day to another with an exponential increment in deaths and the discovery of newly impacted countries.

In addition to this oil demand shock, the oil market also experienced a supply shock. On March 6, 2020, Saudi Arabia and Russia locked horns for dominance over global oil market share. The Saudi Arabian proposal of a reduction in oil supply was rejected by the Russians, which led the Saudis to flood the market through increased oil production. Further, United Arab Emirates also announced its plan to boost oil supply. This news plunged the oil price to $31.05 per barrel on

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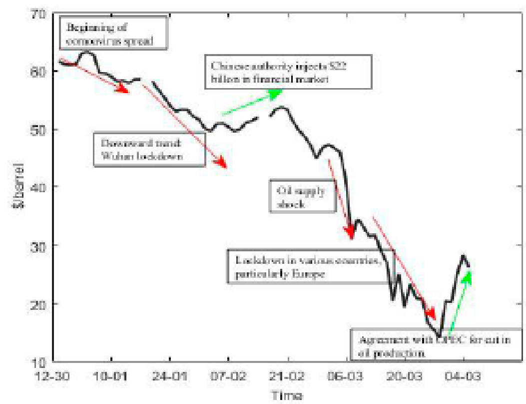

Figure 1. The dynamics of oil prices under the coronavirus disease

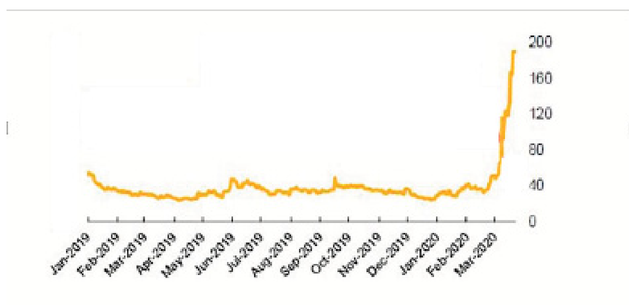

Figure 2. CBOE crude oil price volatility
Source: Bloomberg Finance LP.

March 9, 2020, with a 20% loss in price, further leading to a financial crash on the same day.

These shocks in demand and supply generated financial market stress (Figure 2). The high level of uncertainty, echoed by nervous market sentiment, also saw the recent spectacular rallying of U.S. government bonds, as the 10-year yields fell from 1% to 0.4%. This rallying can be explained by understanding the intention of people to rush for safety through institutional investments.

Overall, the impact of COVID-19 on the oil markets can be explained through two mechanisms. First, based on the output channels; the restrictions on traveling, supply chain, and workers' mobility due to strict measures in place to limit the contagion have plunged the industry into inactivity. Consequently, the consumption of oil and oil-based products has reduced dramatically, leading to a sudden reduction in the demand for oil. The second effect is related to the effect of the stock market on the oil market, especially within the context of rising uncertainty and anxiety in market sentiment. This negative sentiment within the oil market led to pessimistic expectations concerning oil demand, prompting flight away from energy stocks and leading to further price decrease.

Oil industry outlook

Oil demand & consumption

The coronavirus disease has now spread to more than 100 countries. The delay in propagation across countries implies that the lockdown of the main importing countries may be spread out over the entire first half of 2020. From the beginning of January to April 8, 2020, China adopted serious containment measures, such as the lockdown of Wuhan region, that severely constrained economic activity. During the first quarter of the year, Chinese oil demand saw a significant year-on-year drop because of confinement measures, as the economy slowly came to a halt.

From the beginning of March, Italy locked itself down completely, while France moved on to this strategy on March 17; the lockdowns are expected to remain until mid-May, at least, for both countries. In the United States, between the mid of March and beginning of April, some states began taking sweeping containment action while others took a more limited approach. A similar reaction was adopted by India on March 25. It is expected that the lockdown will remain in some key oil importing countries until June, at least, in an optimistic scenario.

Although the economic situation in China has improved after lockdowns were eased off in some regions beginning in the second quarter of 2020, the conditions remain extremely volatile in other key oil importing-countries, which have maintained their oil demand close to the levels in the first quarter. For the rest of 2020 (third and fourth quarters), we expect a smooth improvement in oil demand, as a basic scenario. Easing of lockdowns in different countries, however, does not imply removal of constrained measures, such as limits on traveling and tourism activities, which impact oil consumption. From January to end of March, the oil demand decreased from 100 mb/d to 92 mb/d. We expect that in April, May, and June, the oil demand will be around 90 mb/d, as most of the oil importing countries are still in lockdown or will continue adopting restrictive measures during this period. We expect that the oil demand will recover from the beginning of the third quarter of 2020 in a progressive manner.

Oil supply

The level of oil stocks around the world is currently estimated at 4.5 billion barrels by Rystad Energy (independent energy research and consultancy firm). This level represents 80% of the world's storage capacity. The strategic level of oil stocks for countries has been largely reached and the storage costs are only increasing, with a level of supply surplus having never reached before. The evolution of this surplus will depend on the deal between various oil producing countries, but one thing is certain: under current conditions, this surplus will only increase. In February, oil supply fell by 580 kb/d, as Libya's production reduced. The deadlock between Saudi Arabia and Russia, and the matter of flooding the market with oil supply, should end by April 09. OPEC announced a reduction of 10mb/d during May and June, with a further reduction of 8mb/d for the rest of 2020. In 2020–2021, the reduction is estimated to be around 6mb/d. We suggest that this supply figure is an appropriate outlook for this crisis.

Oil refinery industry

The coronavirus outbreak has led to drastic measures being taken in various countries, affecting the international supply chain, and reducing transportation and individual mobility to limit the spread of the virus. For the first quarter of 2020, the reduction in consumption of oil products led to the downward revision of refining intake by 1.2 mb/d, primarily because of China. February runs are estimated at 10.1 mb/d, down 2.7 mb/d, year-on-year. We expect that the margins of the second quarter of 2020 will be around those of February, supported by the oil price reduction in March 2020. With oil prices below $30 a barrel, companies have no choice but to reduce their investment and cut additional jobs.

Oil outlook discussion

The oil outlook will depend on the commitment of governments and their policies to contain the coronavirus outbreak. However, it is worth highlighting the characteristic of the oil market in that there is no global governance of the price per barrel. In addition to the law of supply and demand, there is a balance of power between producer countries, which has a direct impact on prices. Moreover, the cost of production is not the same for all producer countries. The U.S. has a higher production cost than Russia, and both have a production cost that is almost twice that of Saudi Arabia. Therefore, the challenge is to find a level of production that will allow convergence towards the fair price of oil; that is the level that will ensure the profitability of production investments without killing the demand for oil. The oil demand will surely be below the level of 2019, as some behaviors and routines will be changed indefinitely, especially regarding production systems, offshoring industries, trade, and traveling. Today, we are experiencing a high level of uncertainty caused by the outbreak of this pandemic, and there seems to be little clarity in this uncertainty. Perhaps the only certainty that we have at the moment is that life will be transformed into a completely different shape and structure after this outbreak is controlled, and nobody knows for sure what the new normal will be like.

Footnote

1 For more details on the theoretical transmission channels between oil and stock markets, please see Stavros Degiannakis, S., Filis, G., Arora, V. 2018. Oil Prices and Stock Markets: A Review of the Theory and Empirical Evidence. Energy Journal 39 (05), 85-130.

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COVID-19 - Final Straw or Deathblow for a Global Coal Industry at the Verge of Collapse

BY PAO-YU OEI, PAOLA YANGUAS PARRA, CHRISTIAN HAUENSTEIN

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Introduction: The status quo of coal

Coal accounts for around a third of global primary energy supply, is mostly (~70%) used for power and heat generation, and responsible for 40% of global CO2 emissions (IEA 2020a). Within the last years, coal-related businesses have been increasingly exposed to climate and air pollution regulation, local resistance to projects, climate litigation, trade restrictions, and reduced operational margins due to competition with alternative fuels. These policy and market developments have increased the risk profile of coal related businesses significantly resulting in estimated stranded assets ascending to hundreds of billions (Caldecott et al. 2016). Key indicators show the early stages of decline of the global coal industry with coal use peaking in 2014 and showing a plateau since then (IEA 2020a) as well as global coal prices being on a downward trend (Enerdata 2020) (see Figure 3).

In 2019, global CO2 coal emissions fell by 1.3% – offsetting increases in emissions from oil and natural gas (IEA 2020b). While this is an encouraging sign for global decarbonisation efforts, the scale and speed of the reductions in coal use and production are far from what would be needed to reach global temperature targets agreed on by governments (Climate Analytics 2019; Stockholm Environment Institute et al. 2019). Still, many countries – mostly in the Global South – are planning to expand coal use in the coming decades (Shearer et al. 2020), with current and stated policy scenarios of the latest World Energy Outlook, showing a slight increase or flattening of coal emissions until at least 2030 (IEA 2019).

Within this context, key policy and economic developments in 2020, driven by the ongoing COVID-19 pandemic, can be determinant for the medium and long-term future of coal markets – and therefore also influence the possibility to reach overall global climate targets. Within this perspective, we examine how the pandemic, and subsequent economic recession, will affect global coal markets and coal dependent countries and regions (see Figure 1). Avoiding mistakes of the post 2008-financial crisis period, however, we believe that this can also accelerate the transition towards a more sustainable development pathway.

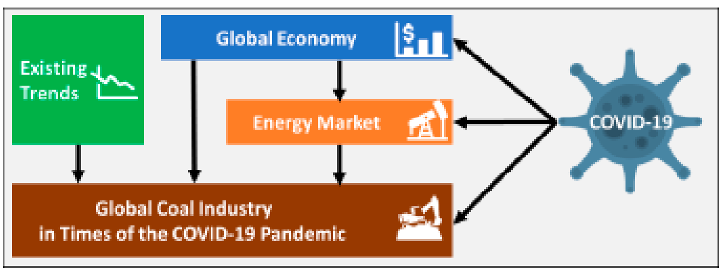

Figure 1: Prospects for the global coal industry in times of a COVID-19 pandemic.
Source: Own depiction.

Effects of the COVID-19 outbreak on the global coal market

The COVID-19 pandemic is an unprecedented global health crisis which causes partial and total lock-downs of countries until 2021. Even in the best-case scenario this will go along with hundreds of thousands of people dying and enormous social and economic consequences for societies. In addition to these direct consequences of COVID-19, also the global economy and energy markets, are largely affected by the pandemic and its countermeasures (affecting once more societies).

The COVID-19 pandemic has resulted in an unprecedented sudden halt of the global economy in spring 2020. National lock-downs and the closure of main industry branches reduced the overall need for labor, products as well as energy. The interruption of international trade and transport furthermore interrupted global supply chains – affecting even those countries and industries that were (not yet) hit by the virus itself. As a consequence, investments are being withdrawn within all areas, but especially from developing countries, generating heavy depreciation of local currencies (IMF 2020).

Increased government spending combined with a global economic recession increases overall debt levels substantially, including major coal producers and exporters. This becomes a problem especially for countries suffering already from high debt levels. Some of these countries have just recovered from the financial crisis of 2008 and are still struggling to achieve their sustainable development goals. Furthermore, fear of massive government debt default, could unleash catastrophic failure of global financial markets.

The unanticipated reduced demand for energy also increases the pressure on international fuel prices. This comes at a time of already low fuel prices due to ongoing discussions among oil producing countries. Some countries (and companies) are more vulnerable to such resulting price shocks. This can be due to higher production costs (e.g. in the U.S), or a higher dependency on fuel rents (e.g. in the Middle East). Fuel price drops therefore strongly affect national budgets as well as currency depreciation, and consequently can decrease economic or political stability of countries and regions (Westphal et al. 2019).

The coal industry is therefore already indirectly affected by the global economic recession, reducing the demand for coal (e.g. in the steel industry), the drop of fuel prices which increases the competition (e.g. natural gas as competitor in the electricity market), as well as economic instability in financial markets and national budgets. In addition, also direct effects by the COVID-19 pandemic can be observed as mining and power plant activities around the globe were reduced and in some cases even stopped to limit the spread of the virus (see Figure 2):

The U.S. is estimating a 20% reduction of coal production and consumption for 2020; in April 2020 European countries are observing electricity demand reduction of 10-40%, Hubei province in China still observes a 30% electricity demand drop; India's coal consumption in March was reduced by 30%. In addition, the construction of coal power plants was delayed due to shortages of workers, resources or financial reasons, comprising of more than 13 GW of delayed capacity in South and South-East Asia alone (Global Energy Monitor 2020).

These negative effects will keep global coal prices at their current low levels and might even result in a temporary downturn. Coal prices have already declined 8% y-o-y in 2019 due to declining demand in the OECD coupled with flattening demand in China not compensated by increases elsewhere. Since the COVID-19 outbreak, thermal coal prices have remained resilient, although at low levels, amid sharp losses in other fossil-fuel markets.

Further trade restrictions, predicted continued oversupply in the seaborne coal market, as well as disruptions in the supply chain are expected to have a negative impact on international coal prices (Kalb and Sands 2020). This leaves coal exporting countries on a very risky position, given their high dependence on coal revenues and royalties.

The COVID-19 pandemic will reduce global energy as well as coal demand in 2020 substantially and increase competition among the fossil fuel industry. However, coal's midterm perspective hereby strongly depends on the duration of the pandemic as well as on different possible economic recovery strategies.

Experiences from previous (economic) crisis, however, show that the economic performance – and emission levels – could return to its pre-crisis levels within a couple of years. China, appearing to have already passed the first wave of its COVID-19 crisis, is trying to reboot its economy also through the construction of new coal power plants resulting in 8 GW of additional new coal capacity in March 2020. (Global Energy Monitor, 2020).

The uptake of the continuously rising share of renewables, however, will be determining the fate of all fossil fuels. Neither oil nor natural gas are compatible with the vision for a carbon-free economy. Their consumption levels, however, appear unlikely to change too much within the next ten years (IPCC 2018). The prospects for coal, on the other hand, look much more pessimistic (see Figure 2).

Upcoming challenges for coal

Prevailing challenges for the international coal market

		Short-term effects (2020)		Medium-term effects (2021-2025)		Long-term effects (2025+)	
Global Economy	Globalization	Global shut-down	↓	Ongoing travel and trade restrictions	↘	National critical infrastructure build-up	↗
	Economic Growth	Global recession	↓	Ongoing recession in some countries	↘	Uptake to previous growth rates	↗
	Emissions	Strong reduction due to recession	↓	Reduced reduction depending on economic uptake	↘	Climate policies might halt emissions despite economic growth	→
Energy Sector	Energy Demand	Strong reduction due to recession	↓	Reduced reduction depending on economic uptake	→	Uptake to previous rates	↗
	Gas & Oil Demand (& Prices)	Strong reduction due to recession and lower energy demand	↓	Stabilization in low-medium range (aviation will stay low; disunity of producers)	→	Stabilization in low-medium range (climate policies)	→
	Renewables Installments	Reduced investments due to recession	↘	Competition by reduced fuel prices; high upfront investment costs	→	Innovation lowers prices; supportive climate policies	↗
Coal Industry	Coal Demand (& Prices)	Reduction due to recession and lower energy demand	↘	Competition with other energy carriers, reactivation of supply and trade chains	→	Competition with other energy carriers and climate policies	↘
	Investments in New Infrastructure	Halted due to recession, delays in projects under development	↓	Divestment increases, focus on exploiting existing mines, power plant projects cancelled or shelved	↘	Continuous divestments, except domestic production and cheap mines	↘
	Coal Regions and Workers	Halted productions and job losses; reduced fiscal revenues for export-depending countries	↓	Continuation of open mines, but hardly any new investments; changes in employment and economic structure	↘	Coal phase-out begins with various degrees of national support schemes for a just transition	↓

Figure 2: Summary of main trends: Short-, medium-, and long-term effects of the COVID-19 pandemic on global economy, energy sector, and coal industry.

Source: Own depiction.

Even before the COVID-19 pandemic crisis, the global coal industry was already facing some fundamental challenges resulting in narrowing operational margins for coal related businesses both on the supply and demand side (Oei and Mendelevitch 2018). COVID-19 is likely to exacerbate all these key challenges

Starting with the World Bank in 2013, and growing fast after 2015, the list of financial actors that have enacted anti-coal policies is now very significant, with combined assets ascending to trillions (see Figure 3) (Buckley 2019). As a result, less capital is available for coal related businesses and the risk profile of coal-related businesses is much larger (Mercure et al. 2018). Moreover, there is the increasing awareness of importance of climate change risk management, and climate finance (Asia Investor Group on Climate Change et al. 2019). Consequently, considerably less capital at higher interest rates is available for coal related businesses. The focus of investors during and after the COVID-19 pandemic will therefore lie on maintaining current operations, but in most cases be difficult to finance new mining or coal power plants projects.

Also the financial situation of important coal companies has deteriorated continuously in last years, both on the supply and demand sides (Michalak 2017): Rio Tinto sold its last coal mine already in 2018; in 2019 additional announcements came from BPH to exit thermal coal operations in Australia and Colombia; Anglo American to move away from thermal coal and reduce its thermal and metallurgical coal production plans; and Glencore to start aligning its business model with the Paris Agreement (Umar 2020). This precarious financial situation of coal companies, combined with capital scarcity will make it difficult for the industry to find financial support in times of crisis.

Another fundamental challenge for coal-related businesses globally, is the increasingly grim outlook for long-term coal demand. Since 2015, 170 GW of coal power generation have retired, a trend that is expected to continue in the next decade, while the global coal power plants pipeline has shrunk 74%, with hundreds of projects being shelved or cancelled (Shearer et al.

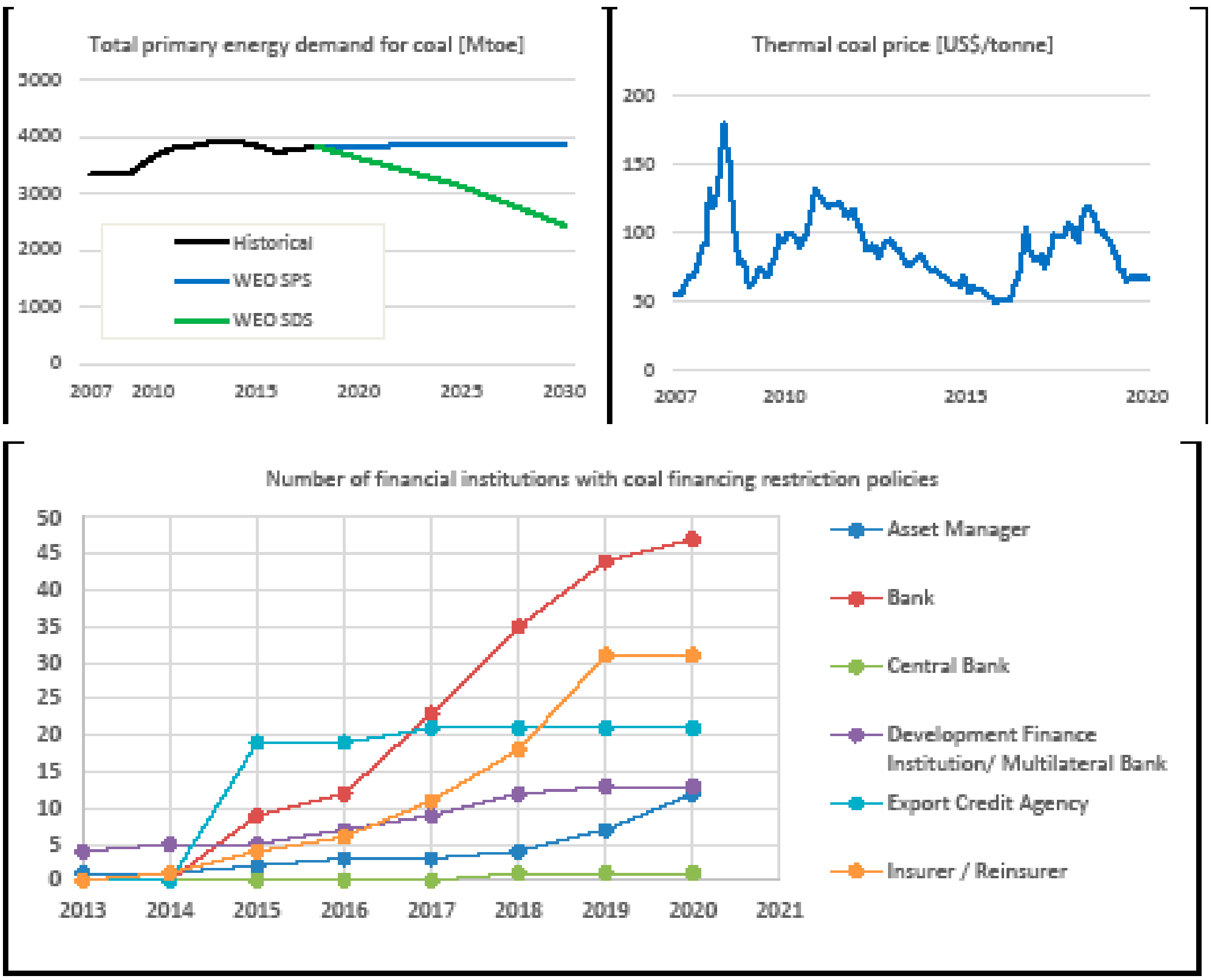

Figure 3: Status quo and prospects of coal in 2020

Source: Own depiction based on IEA data, IndexMundi.com and IEEFA database. Note: Global primary energy demand from coal, historical vs World Energy Outlook 2019 scenarios (top left); Thermal coal price (FOB, US$/metric tonne) at Newcastle, Australia (top right), Overview of number of financial institutions with coal financing restriction policies by type of institution and year of

2020), and coal demand projections (e.g. IEA World Energy Outlook) have been systematically corrected downwards. Updated negative GDP growth projections will likely result in a much larger decline in coal demand than expected only a few months ago (IMF 2020). Moreover, growing intentions of key global players to focus their recovery and stimulus packages in the promotion of a 'Green Deal' and clean energy could speed-up already discussed coal phase-out plans, both for thermal and metallurgical coal.

On the demand side, investments in new renewable energy capacity have surpassed coal in all relevant markets for several years already; since 2019 also around 60% of the global coal fleet is outcompeted by renewable energy even in terms of operating costs (Carbon Tracker Initiative 2020a). Consequently, 60% of the operating coal capacity will be cash flow negative by 2030 under competitive market conditions (Carbon Tracker Initiative 2018). While lower fuel prices could provide an incentive for increased used of coal power plants, carbon pricing, air pollution standards, and lower prices of alternative fuels make it unlikely that we observe a reversal of current negative trends on coal power generation, unless active government intervention in favour of coal is executed. Consequently, estimates by Carbon Tracker (2020) suggest that the impacts of COVID-19 on the economics of coal power plants would be very limited and in 2020, roughly half of the operating coal fleet globally will be cash negative.

Avoiding mistakes from post-2008-financial crisis times

As a consequence of the 2008 financial crisis, the thermal and metallurgical coal market experienced a significant slowdown, with coal demand eroding, prices plummeting, and growing project financing costs (Rademacher and Braun 2011) (see Figure 3). Global coal demand (and prices) only bounced back in 2010 driven by strong Asian demand. Expectations of continuous growth of demand spurred investments by coal companies in the post-crisis period in mining activities, but also asset acquisitions (IEA 2012). However, already in 2012, prices started to decrease again and the expected further growth of demand did not materialize. Left with large debt from prior asset acquisitions, many coal companies went bankrupt (Mendelevitch, Hauenstein, and Holz 2019).

Betting on post-crisis economic upturn after COVID-19 and investing in coal resources could lead again to massive amounts of wasted capital as the industry has a clear negative mid- and long-term outlook and would therefore not be sustainable investment. Although the coal industry was struggling already before the COVID-19 pandemic, it is attempting to get funding or other benefits from stimulus packages (e.g. preferential credit or direct cash transfers) and lobby for relaxation of environmental standards. A second observable strategy is the attempt to socialize (e.g. nationalize) coal industry's losses and privatize their wins (e.g. request of tax or royalties exceptions, massive dismissal of formal and informal workers justified on the crisis, or accelerated bankruptcy submissions).

Conclusions and Policy Recommendations

With global coal use and emissions showing a peak and plateau after 2014, we argue that the 2015 Paris Agreement marked a no-return point for the global coal industry, which since then has entered into the early stages of a long-term decline. Some of the key challenges and trends that indicate evidence of this inflection point for the global coal industry include: decreasing capital availability and increasing risk profile; negative outlook for future coal demand; uncertain outlook for international coal prices; and deteriorating operational and financial indicators of coal-related businesses.

The coal industry is being hit directly by COVID-19 in times were it already suffered from economic stress and political pressure for environmental and climate reasons. In addition, health problems and pollution caused by, among others, emissions from coal power plants might worsen negative health effects of the pandemic. All of this will make it difficult for the industry to find urgently needed financial support in times of crisis. Moreover, direct and indirect effects of COVID-19 are likely to exacerbate all challenges the coal industry is already facing.

Unlike after the 2008 financial crisis, now virtually all the countries in the world have ratified an international Climate Agreement, and have enacted national greenhouse gas emissions reduction targets. Under these new circumstances, it is likely and highly beneficial that countries and multilateral organizations focus much more in green investment recovery packages than in the recovery of the 2008 crisis. With this, the COVID-19 crisis and its aftermath could be a golden opportunity to accelerate global coal phase-out and bring global decarbonization and just transitions efforts substantially forward.

However, mistakes from the past must be avoided and concentrated policy efforts will be needed to deal with the economic and social consequences of this dying industry, in particular in coal-dependent countries and regions, where the crisis will hit especially those at the bottom. Stimulus packages should be designed (and justified) in a way that proves how it contributes to longer-term efforts to decarbonize national economies and meet the sustainable development goals.

Concrete policy recommendations for the coal sector should therefore include:

- Incentivize alternative industries in coal regions and start planning for a time after coal (taking advantage of the increased awareness of the vulnerability of coal-dependent regions and the inevitable decline of coal).

- Focusing public resources in coal-dependent regions on mitigating the effects of the crisis on the most vulnerable (e.g. making aid packages to coal companies conditional on maintaining employment, social security, and health and security of the employees).
- Reconsider all investments in new coal infrastructure, including coal power plants and mines, by – at the very least – withdrawing public funding for them.
- Revising carefully aid requests by the coal industry, to distinguish the relative importance of COVID-19 related issues, compared to other market trends, and financial and managerial decisions, and communicating transparently the decisions about resource allocations.
- Derogation or weakening of environmental standards and regulations (e.g. air, water and soil pollution standards) should not be considered as crisis-relief measures.
- Make fund transfers or tax exemptions (e.g. accelerated depreciation schemes) conditional on plans to phase-down emissions from the sector in the medium and long term.

Following these policy recommendations, the aftermath of the COVID-19 pandemic can help to enable a successful energy transition and at the same time redirect formerly coal dependent regions into a more sustainable future – even if this will mean a deathblow to an already dying coal industry.

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Covid-19 and Social Distancing: Does It Show Up in the Demand for Electricity?

BY STEVEN PERCY AND BRUCE MOUNTAIN

Empty motorways and airports make it obvious that movement restrictions and stay-at-home regulations have had a big impact on the demand for oil and petroleum products. But what impact have these restrictions had on electrical demand? We examine electrical demand data measured at high voltage transmission grids to assess the impact of Covid-19 social distancing restrictions in Australia, the United States, New Zealand and Great Britain. Interestingly, New Zealand and Australia have had amongst the lowest per capita infection and case fatality rates, while the United Kingdom and United States have had amongst the highest.

We also review changes in mobility as measured in Google's Covid-19 Community Mobility Reports[1]. We find a strong correlation between mobility trends and aggregate electrical demand. While apparently similar social distancing restrictions in all four countries might have been expected to show up in similar electrical demand and mobility reductions, in fact the picture is very different: electrical demand (and community mobility) declined sharply in New Zealand and the UK. In Australia and much of the United States, electrical demand has hardly changed. Though mobility reduced in the United States and Australia, the reduction in both countries has been much smaller than in New Zealand and the United Kingdom.

Background

The United Kingdom, New Zealand and Australia introduced social-distancing regulations on 23 March, 23 March and 31 March respectively. In the United States these regulations were established by state governments in California, New York, Florida and Texas on 19 March, 22 March, 30 March and 30 March respectively. Some of the other U.S. states introduced similar restrictions around these dates.

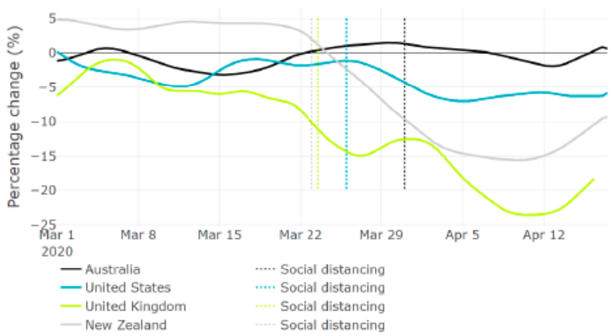

Figure 1 Trend change in aggregate country demand relative to baseline

Source: USA: EIA (US Energy Demand by Region); NZ: Electricity Authority (Latest wholesale trends); UK: National Grid (Data Explorer) and ELEXON (BM Reports), AU: AEMO (NEMWeb). VEPC Analysis

Contemporaneously, border controls and quarantine for international arrivals were imposed in New Zealand, Australia and the United States, but not in the UK.

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See footnotes at end of text.

Change in electrical demand

Figure 1 shows the country-level changes in aggregate electrical demand compared to

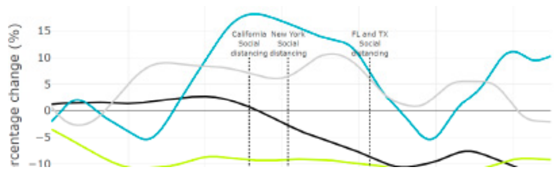

Figure 2 Percentage change in average weekly demand in selected U.S. States, relative to baseline

Source: EIA (US Energy Demand by Region). VEPC Analysis

a historical baseline.[2] Electrical demand in both the United Kingdom and New Zealand declined significantly after social distancing regulations were imposed while demand has been largely unchanged in Australia and has a declined a little in the United States, relative to the baseline.

Figure 2 shows the weekly average change in electrical demand compared to a historical baseline for New York, Florida, Texas and California, and Figure

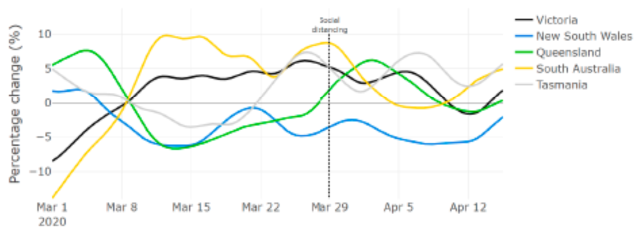

Figure 3. Percentage change in average weekly demand in selected Australian States, relative to baseline

Source: AEMO, NEMWeb. VEPC Analysis

3 shows the same measure in the Australian states of Victoria, New South Wales, South Australia, Tasmania and Queensland.

Figure 2 shows the largest demand reductions occurred in California and New York and that demand increased in Texas and Florida. Figure 3 shows the largest demand reductions in New South Wales, almost

	Country/state	Retail and recreation	Workplace	Average
	New Zealand	-88	-70	(79)
	United Kingdom	-81	-65	(73)
United States	New York	-62	-60	(61)
	California	-48	-55	(52)
	Florida	-45	-40	(43)
	Texas	-40	-42	(41)
Australia	Victoria	-42	-40	(41)
	New South Wales	-40	-40	(40)
	Queensland	-40	-40	(40)
	Tasmania	-41	-38	(40)
	South Australia	-40	-37	(39)

Table 1. Average percentage change in mobility since social-distancing regulations.Source: Google Covid-19 Community Mobility Report, VEPC analysis

no change in Queensland and Victoria and slight increases in Tasmania and South Australia. It is also obvious in these charts that, relative to the baseline, the variation in demand before the social-distancing regulations took effect was at least as large as it has been since.

Change in mobility

The direction of the country and regional demand changes since the introduction of social distancing regulations is consistent with the Google mobility data shown in Table 1. The table shows the average percentage reduction in mobility since the imposition of social distancing regulations.

Table 1 shows that, consistent with the reductions in electrical demand, the biggest reductions in mobility occurred in New Zealand, the United Kingdom and in California and New York. The smallest reductions in mobility occurred in Australia (approximately the same reduction in all states) and in Texas and Florida.

This analysis suggests that changes in mobility as measured at retail & recreation venues and workplaces, and changes in aggregate electrical demand are strongly associated and that average reductions in mobility above 45% are associated with large (10% plus) declines in electrical demand, but reductions in mobility below 45% are associated with little change in electrical demand.

Of course the specific circumstances (particularly climate), the choice of baseline and the economic structure of economies affect demand. A rigorous economic analysis will unearth additional features and can isolate more precisely the impact of social isolation policies. However this indicative analysis suggests that in developed economies, reductions in social mobility and electrical demand are strongly associated but that reductions in mobility of less than 45% in workplaces and recreational spaces have had little impact on aggregate electrical demand relative to the baseline. Reductions above this level in New Zealand, the United Kingdom, New York and California are associated with reasonably large (10% plus) reductions in electrical demand relative to baselines.

Footnotes

[1] Community Mobility Reports aim to provide insights into what has changed in response to policies aimed at combating COVID-19. The reports chart movement trends over time by geography, across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential. The reports can be found at: https://www.google.com/covid19/mobility/

[2] These were calculated by extracting the trend component of the 30-minute aggregate energy demand from 2017 to 2020 using seasonal and trend decomposition (STL) applying locally estimated scatterplot smoothing (Cleveland et al., 1990). The 2020 energy demand trend is compared to the average of the demand trends from 2017 to 2019. No temperature adjustment is applied.

Estimating the Impact of COVID-19 on Emissions and Emission Allowance Prices Under EU ETS

BY KENNETH BRUNINX AND MARTEN OVAERE

Introduction

The COVID-19 pandemic has upended the world economy: factories are idle, planes are grounded, and people are locked in their homes. This decrease in economic activity has significantly decreased energy use and carbon emissions. Evaluating the effect of the first three weeks of lockdown in Europe, we estimate that carbon emissions under the European Union Emissions Trading Scheme (EU ETS) are around 38 MtCO2 lower per month than usual. Under a cap and trade system, this unanticipated negative demand shock would only decrease the price of emission allowances, but not how much is emitted in total under the fixed cap. Starting in 2023, however, a cancellation policy will be in effect, such that a fraction of surplus allowances in the EU ETS' market stability reserve (MSR) will be canceled (see Bruninx et al. (2020) and European Union (2018) for all details). Because the amount of cancellation is conditional on the surplus of allowances, the negative demand shock from COVID-19 might affect both the price of emission allowances and cumulative emissions. Using the long-term equilibrium model of Bruninx et al. (2019), we show across a range of negative demand shocks that the MSR and the cancellation mechanism do exactly what they are designed to do. A negative demand shock has very limited effect on emission allowances prices and is largely translated into lower cumulative carbon emissions.

In the remainder of this paper, we subsequently estimate the size of the negative demand shock in the EU ETS (Section 2) and its impact on emission allowance prices and cancellation volumes (Section 3). Last, we discuss the implications of this analysis and suggest some directions for further analysis.

Estimating the negative demand shock

The European Union Emissions Trading Scheme (EU ETS) limits emissions from the electric power sector, the energy-intensive industry and intra-European aviation. This cap-and-trade system covers around 45% of the EU's greenhouse gas emissions, equaling 1749 MtCO2 in 2018 (European Environmental Agency, 2020). To estimate the size of the negative emission allowance demand shock, we identify the change in monthly emissions from the three sectors covered by the EU ETS below.

First, we estimate the change of emissions from electricity generation, based on the methodology of Ovaere and Gillingham (2019). We run a regression analysis using more than five years of hourly electricity generation by technology from ENTSO-E (2020). Based on this analysis, we are able to identify the change in average, hourly output of carbon-emitting electricity generation technologies due to the COVID-19 pandemic.

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Note: Instead of asking for exact figures, these surveys ask for the direction of change compared to a normal production level. Possible answers are above normal/normal/ below normal. The presented number is the difference between percentages of respondents giving favorable and unfavorable answers, while the "normal" answers are ignored.

		Gas	Lignite	Hard coal	Oil
Belgium	(MWh/h)	-770***	/	/	0
Czechia	(MWh/h)	-69***	38***	-581***	12***
France	(MWh/h)	-1114***	/	58	16
Germany	(MWh/h)	-2861***	-1873***	-2860***	-91***
Great Britain	(MWh/h)	-1037***	/	-1881***	0
Netherlands	(MWh/h)	-41	/	+568***	/
Portugal	(MWh/h)	-1	/	+85***	/
Spain	(MWh/h)	-3433***	317***	1449***	3
Total	(MWh/h)	-9427	-3152	-1519	-59
Carbon intensity	(tCO_2/MWh)	0.374	0.97	1.04	0.624
Change in carbon emissions	(tCO_2/h)	-3526	-3057	-1580	-37

Note: $p<0.05$ (*), $p<0.01$ (**), $p<0.001$ (***).

Table 1 Effect of COVID-19 lockdown in different countries on average, hourly output of carbon-emitting electricity generation technologies (MWh/h)

We add month fixed effects and non-linear time trends to control for regular patterns in generation output and for broader time trends impacting output by conventional generation technologies. We run a separate regression for every carbon-emitting generation technology (natural gas, lignite, hard coal and oil) and in each European country of our sample. In this analysis, we consider Belgium, Czechia, France, Germany, Great Britain, Netherlands, Portugal and Spain. Together they consist of 65% of EU ETS electricity generation.

We find that in our sample, gas generation decreases on average by 9427 MWh/h, lignite by 3152 MWh/h, hard coal by 1519 MWh/h and oil-fired generation by 59 MWh/h (Table 1). This is a decrease of respectively 22%, 19%, 13% and 7% compared to the 2019 average (ENTSO-E, 2020).

Combined with the assumed carbon intensity for gas, lignite, hard coal and oil listed in Table 1, carbon emissions from electricity generation are estimated to be 8200 tCO_2/h lower in our sample. Extrapolating these estimates and correcting for the scope of our sample (65%), every additional month of similar lockdown measures would decrease electricity-related carbon emissions by 9 $MtCO_2$.

Second, aviation has decreased by 90% (Statista, 2020), from a pre-COVID 2018 level of 67 $MtCO_2$ per year (European Environmental Agency, 2020). This leads to a decrease of around 5 $MtCO_2$ aviation-related EU ETS emission for every additional month of similar lockdown measures.

Last, data for idle industrial production is not yet available for March 2020, but we can make an educated guess of the impact by looking at the business tendency survey of European countries for March 2020 (OECD, 2020). For example, the March 2020 future production tendency of manufacturing firms in the Euro area dropped to -9.4, down from 4.7 in February 2020, meaning that in the span of one month, the share of optimistic manufacturers decreased with 14.1%. This decrease is even more pronounced in countries like Italy (-23.9), Czechia (-20.6) or Germany (-18.2). Similarly, the confidence indicator dropped by 28.6 in China in February 2020. We assume that industrial production activity decreased by 50%, or 24 $MtCO_2$ per month from a pre-COVID 2018 level of 584 $MtCO_2$ per year (European Environmental Agency, 2020). Hence, in what follows, we use a negative demand shock of 40 $MtCO_2$ per month that the lockdown is extended in its current form.

The impact on cumulative emissions & emission allowance prices

We analyze the impact of this negative demand shock on the emission allowance price and allowed emissions under EU ETS, leveraging our stylized EU-ETS-MSR model (Bruninx et al., 2019). This model is based on the detailed long-term investment model of Bruninx et al. (2020) and assumes rational, price-taking and risk-neutral firms that optimize their abatement and banking actions over the complete EU ETS horizon. We study three demand shock scenarios, starting from an initial demand shock of 120 $MtCO_2$ (i.e., a three month lockdown) or 240 $MtCO_2$ (i.e., a six month lockdown) in 2020:

A V-shaped demand shock, in which carbon emissions return to a business-as-usual before the end of 2020. The total negative demand shock is, hence, 120 $MtCO_2$ or 240 $MtCO_2$.

- A U-shaped demand shock, which gradually vanishes between 2020 and 2025. In these scenarios, we assume the demand shock linearly decreases from its initial value in 2020 to zero at the end of 2025. The total negative demand shock is, hence, 420 $MtCO_2$ or 840 $MtCO_2$.
- A persistent demand shock, in which 25% of the initial demand shock becomes permanent post2020. The total negative demand shock is, hence, 1470 $MtCO_2$ or 2940 $MtCO_2$.

In each scenario, the state of the EU ETS at the end of 2019 is fixed, based on the records of the surplus in the market, the holdings of the MSR and the emissions up to 2019 (European Commission, 2019). Verified emissions for 2019 are estimated to be 10% lower than emissions in 2018 (Sandbag, 2020).

Since the marginal abatement cost curve the EU ETS is fundamentally uncertain, we run each demand shock scenario with a linear, quadratic and cubic marginal abatement cost curve, following (Bruninx et al., 2019). Baseline emissions are set to 1900 $MTCO_2$, as in Perino and Willner (2017). The discount rate is set to 10% and inflation equals 2% per year. The slope of each abatement cost curve is calibrated to reproduce the average 2019 emission allowance prices (24.7 e/tCO_2, based on EEX (Last accessed: April 1, 2020)) without the negative demand shock. If this calibration yields marginal abatement costs at historical emission levels in 2018 below 0.1 e/tCO_2, this case is not retained in the results (Bruninx et al., 2019).

As a first result, we find in our model that the MSR and its cancellation mechanism are very effective at stabilizing the emission allowance price in response to negative demand shocks. The allowance price in 2020 decreases by less than 0.1e/tCO_2 and this result holds for different marginal abatement cost curves, magnitudes or shapes of the shock. As a second result, we find that the demand shocks differ in their effect on cumulative emissions. In general, short-lived V- and U-shaped shocks are translated largely into lower cumulative emissions, because the MSR absorbs and cancels the increased allowance surplus. On the other hand, persistent demand shocks decrease cumulative emissions much less, as a significant part of the demand shock occurs far away in the future, after the market stability reserve has stopped absorbing and cancelling emission allowances.

In reality, however, the price of EU emission allowances has dropped significantly, by around 6 e/tCO_2. Because this does not happen in our model with rational, price-taking, risk-neutral and perfectly optimizing firms, we adapt our model such that we do observe price shocks. We do this by assuming that firms temporarily change their discount rate by one to eight percentage points during the shock. A temporary change in discount rates makes banking of allowances during the shock less profitable, i.e., it is better to secure the required allowances for future emissions after the shock. This may reflect the situation that many utilities and companies face today: as their financial positions are stressed, they may liquidate assets – such as emission allowances procured to cover future emissions – to improve their cash position. Similarly, they won't have cash to spare to bank emission allowances for compliance with future emissions. Note that in the persistent demand shock

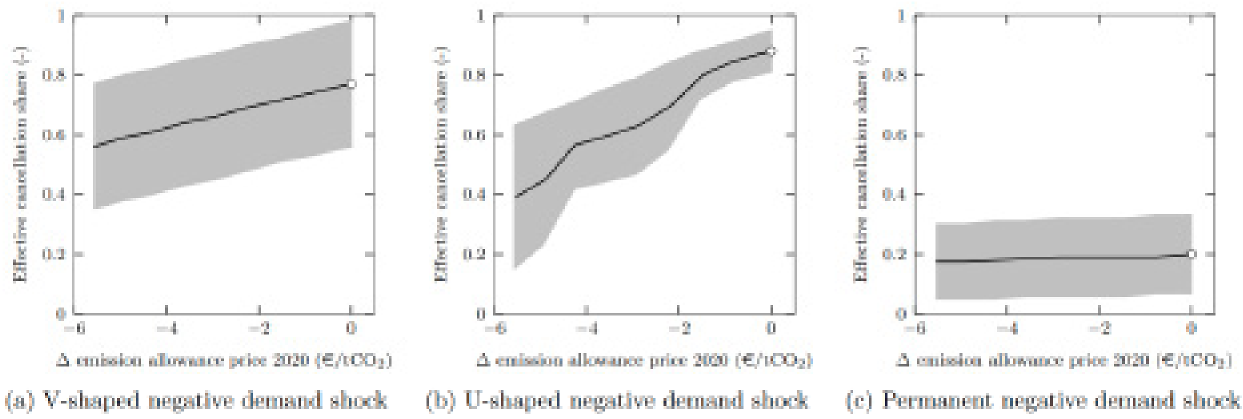

Figure 1 Summary of the results, separated according to the type of shock. The change in emission allowance price in 2020 is calculated by comparing the calculated emission allowance prices before and after the shock. The effectiveness of the negative demand shock is calculated as the change in allowed emissions over the simulated period (2019-2060) before and after the negative demand shock relative to the magnitude of the demand shock. An effectiveness of one means the cumulative emissions under the EU ETS decrease with an equal amount as the negative demand shock as a result of the market stability reserve's cancellation policy. The white-filled marker is obtained without a shock in the discount rate. The change in emission allowance price increases with the shock in the discount rate.

scenarios, these changes in discount rate are only enforced in 2020, whereas we assume the discount rate to evolve linearly to its original value in the U-shaped demand shock scenarios.

Figure 1 summarizes the impact of all three emission allowance scenarios on the emission allowance price (x-axis) and on the cumulative emissions cap (y-axis), represented by the effective cancellation share, which is the fraction of the demand shock that translates into lower emissions. The white-filled marker in Fig. 1 presents the average result without any change in discount rates, while the black line shows how the emission allowances price and the effective cancellation share on average drop when the future becomes less important (modeled by changing the discount rate). The gray area represents the uncertainty around this average, from the six modeled scenarios (two shocks magnitudes times three curvatures of the marginal abatement cost curve). This figure shows that the emission allowance price does not decrease because of the negative demand shock as such, but because of changes in market participants' importance of the future. Remarkably, we also find that the temporarily decreased emission allowance price leads to a lower effective cancellation share. This happens because emission abatement is temporarily less profitable, such that part of the negative demand shock is offset by lower abatement, before the surplus is absorbed and canceled by the market stability reserve.

Conclusion

The COVID-19 pandemic has brought the world's economy to a standstill. In this paper, we estimate the impact of this temporary downturn in economic activity on carbon emissions under the European Emission Trading system, its emission allowance prices and the effectiveness of its market stability reserve to absorb these demand shocks. First, we show that the current lockdown measures lead to emission reductions around 38 $MtCO_2$ per month: 9 $MtCO_2$ per month due to reduced electricity consumption, 5 $MtCO_2$ as the result of reduced intra-European air traffic and 24 $MtCO_2$ in avoided industrial emissions. Second, we illustrate that such negative demand shocks as such do not explain the observed drops in emission allowance prices, as the market stability reserve is able to absorb these demand shocks to a large extent. However, if temporary changes in companies' perception of the profitability of banking emission allowances lead to price decreases, a rebound effect may occur, leading to lower effectiveness values. Hence, if one reduces the impact of an event such as the COVID-19 pandemic to the emission allowance demand shock as such, one may overestimate the ability of the market stability reserve to absorb these shocks.

The presented analysis is, however, based on a stylized representation of the abatement options and costs under EU ETS. Exploring more detailed representations of these abatement options and costs, as in Bruninx et al. (2020), as well as the impact of an event like the COVID-19 pandemic on these abatement costs and options, e.g., through changes in fuel prices, may lead to additional insights. Further work may also focus on the exploration of the impact on emission allowance price paths beyond 2020 and price path recovery.

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(continued on page 54)

COVID-19 Induces Emissions Cut and the Development of the Digital Economy

BY BANGZHU ZHU AND LIN ZHANG

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The quarantine policy in China for controlling the spread of COVID-19 has led to suspension of city operations, including entertainment activities, tourism, transportation, and shopping. Traffic data shows that the number of passengers dropped by half compared to 2019. Factories have been shut down completely and the Purchasing Managers' Index fell to 35.7, which is an historically low record. Satellite images released by NASA shows COVID-19 has dramatically reduced pollution throughout China (NASA, 2020).

The energy sector is heavily affected by the current health crisis. Our estimate suggests that the outbreak of coronavirus reduces China's energy consumption and thus greenhouse gases, in particular carbon emissions, in the short run. In February, coal consumption for electricity generation was reduced by 63.3 Mt, equivalent to about 142 million tons of reduction in carbon dioxide emissions. The consumption of natural gas was reduced 2.76 billion cubic meters, corresponding to an emission reduction of 6 million tons. State Grid Energy Research Institute estimated that the outbreak of COVID-19 has reduced the demand for oil by 3 million barrels per day, about a 20% reduction. The reduced emissions from oil consumption is about 36 million tons. In total, the epidemic control policy has lowered China's carbon emissions by over 184 million tons in February. If emission from production of other industrial sectors are considered, the total number will be much higher.

Such reduction is expected to persist in the long run. This may finally change the emission trajectory of greenhouse gases not only in China but also worldwide, as the duration is being prolonged and the number of countries being quarantined increases. According to the World Health Organization, infections have been detected in over 100 countries (WHO, 2020). An increasing number of countries and regions have been locked down. The emissions of greenhouse gases in these regions will decline accordingly in the coming months.

The COVID-19 epidemic will continue its impact of cutting carbon emissions in the long run through structural change of industry mix and energy mix. The shutdown of production exacerbates the overstocking of bulk commodities such as steel and cement. This will crowd out excessive production capacity of those high-emitting industries. In addition, governmental supporting policy aimed for firms to survive excludes emission intensive industries, while digital and high-tech industries experience explosive growth as the streamline of online work and education creates new demands. The energy transition towards renewables also cuts carbon emissions.

China's experience has also shown the power of the information network and digital society on curbing the spread of coronavirus. Information on COVID-19 infection was limited before January 20, 2020. The announcement of "human-to-human transmission" on that day provoked public panic and supply shortages. The Chinese central government responded swiftly to report the number of confirmed cases on a daily basis and asked local governments of all levels to disclose the statistics at least once per day. This significantly helps eliminate potential social unrest.

Four days later, WeChat, the Chinese version of Twitter, was connected to the Inspection platform of the State Council. In two days, it received 75 million visits. Besides providing timely official information, it offers the public a channel to report any local information on the epidemic, and it also connects to 220 hospitals for online services. The WeChat platform service has been used over 1.7 billion times in the 20 days after going online. Similar service is also offered by Alipay, a counterpart of Apple pay. People in China can now access the recent update of COVID-19, both within the country and abroad.

As the quarantine continues, China is moving towards digitalization. Online conferencing and online education are turning into a routine in Chinese people's daily life, thanks to the high penetration of the internet and coverage of mobile devices. The digital network helps the government restore public confidence in quickly defeating the coronavirus, by disseminating information in a transparent and timely manner; meanwhile, the coronavirus has significantly accelerated the development of the digital society. AI technology and 5G technology have been adopted by many more cities and provinces in China following such practice as it significantly reduced the risks of infection.

Scientists worry that weaker health-care in vulnerable nations will slow the defeat of the coronavirus (Mallapaty, 2020). We urge high-risk countries to learn from the Chinese experience. Countries may further develop their 5G technology and information infrastructure in the near future, which will accelerate the structural change of the economy and thus lower its greenhouse gases emissions. However, one environmental threat of digitalization is the potential increase in emissions from growing electricity demand, as electricity is mainly generated using fossil fuels in China. Therefore, the development of renewable energy, or storage technology for renewables has to speed up to meet such demand.

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Changes in Electricity Demand Pattern in Europe Due to COVID-19 Shutdowns

BY MICHAŁ NARAJEWSKI AND FLORIAN ZIEL

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Introduction

The ongoing coronavirus pandemic in 2020 and especially the preventive measures to reduce the COVID-19 disease changed drastically the patterns of our behaviour. Many countries in Europe and in the world introduced multiple levels of restrictions: companies sent their office employees to work from home, schools and universities closed, many factories limited or stopped their production, curfews and similar stay-at-home orders. All these factors impact the energy demand by decreasing the overall level and changing its behaviour. In this paper, we analyse the change in electricity demand pattern in selected European countries caused by the COVID-19 shutdowns.

For the analysis we consider the five most populated countries of the European Union: Germany, France, Italy, Spain and Poland. The spread of the coronavirus as well as the undertaken coronavirus measures are on multiple levels in these countries in spring 2020. Also, the demand shifts are different for each of the countries which is depicted in Figure 1. In Europe, the pandemic started in Italy and this is also reflected in the electricity load change in Figure 1. A very high rise of the number of infected people in the beginning of the outbreak resulted in a very strict lock-down in the whole country (Flaxman et al., 2020; Saglietto et al., 2020). Thus, we focus particularly on the electricity demand of Italy. The coronavirus started spreading later in the other analysed countries and therefore at the time of this analysis its progress differs significantly – from very similar in Spain to much lower in Poland.

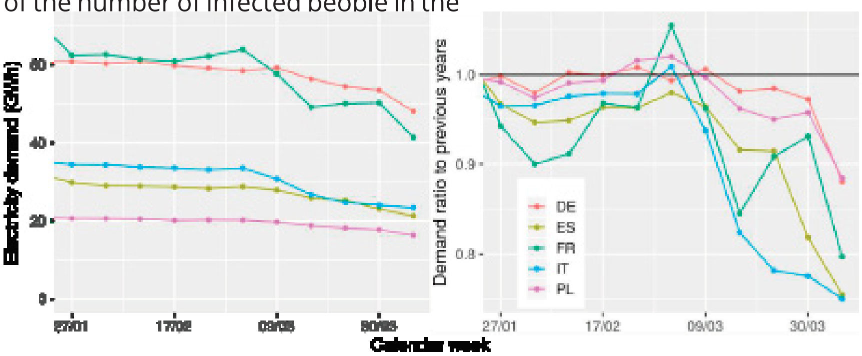

Figure 1: Median weekly average electricity demand (GWh) in years 2016-2019 (left) and the 2020 demand ratio to the average in years 2016-2019.

In the next section, we present the data used for the analysis of the electricity demand. Then, the utilized methodology and the model are discussed. The fourth section consists of the results which are presented and analysed separately for Italy and for the other countries. The last section concludes the paper.

Electricity demand data

The data utilized in purpose of this exercise was downloaded from the publicly available ENTSO-E (2020) Transparency platform. We use the actual total load data of all mentioned countries, and they span the data range from 1 January 2016 to 15 April 2020.1

A small part of the data is presented in Figure 2. It shows the electricity demand in Italy over time during the ongoing pandemic. Moreover, we highlighted the dates of four nationwide shutdowns. The shutdown of all schools and universities does not seem to have impacted the electricity load in Italy. Only the introduction of the national quarantine and then tightening of the lock-down by closing down all non-essential commercial and retail businesses seem to have first impacted the demand. Then, halting all non-necessary production and industries seem to have deepened the decrease. However, the plotted time interval is also the beginning of spring. At this time of the year, a decrease of Italian electricity demand is usually observed. Therefore, in order to recognize whether the change in the load is shutdown-, season-, or weather-driven we need a sophisticated demand model to disentangle the reduction effects.

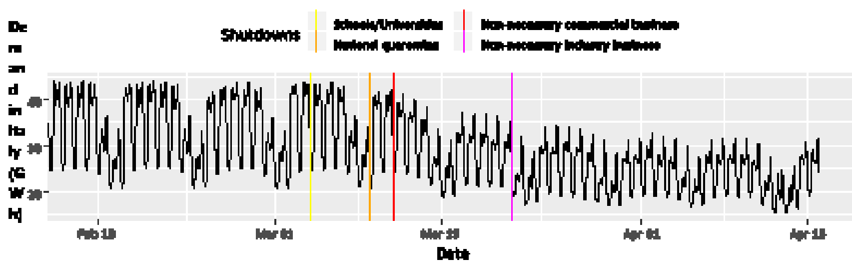

Figure 2: Electricity demand (GWh) in Italy during the ongoing pandemic. The vertical lines indicate shutdown dates.

[1] Minor missing values were interpolated linearly. Additionally the data is aggregated in hourly intervals.

Methodology

For exploiting the structural changes in the electricity demand due to the shutdown we apply a high-dimensional time series change-point models to the electricity log-load of each country. As baseline for the analysis of the structural changes we consider a model that is very similar to the load forecasting model of Ziel and Liu (2016) that was successfully applied in the framework of the Global Energy Forecasting Competition 2014 for electricity load forecasting. We refer for technical details to the aforementioned paper. However, here we want to describe the relevant model properties that are important to understand and interpret the results. For the analysis we consider a baseline model that assumes no structural changes in the data. Then, this model is augmented by change-point components.

First, we describe briefly the baseline model, to proceed with the change-point part.

3.1 Baseline model

The baseline model contains mainly two types of components i) pattern-based time-varying coefficients and ii) autoregressive effects. The time-varying coefficients vary mainly seasonally and capture daily, weekly and annual effects. For the annual effects we distinguish between calendar-based effects (e.g., an effect that occurs every specific calendar date, e.g. Christmas on 25 December) and effects that are driven from the meteorological cycle with a periodicity of 365.24 days. The latter contains rather smooth changes as the meteorological impact changes smoothly over the year. Further, the model contains interactions between the seasonal components, especially the daily cycle may change over the year. Next to date-based calendar effects we also include other calendar effects. Most notably holiday effects from public holiday that have a varying date, e.g., Easter Monday. The intercept of the considered model changes with all the mentioned time-varying components.

The autoregressive components contain historical load data from the last hour up to the last weeks. However, we only let the most recent information to vary over time with selected time-varying components, but keep the remaining autoregressive terms constant. The autoregressive components absorb a lot of information from the past, indirectly also the information from typical external regressors like temperature. Here, we want to remark that we double-checked that the additional information of temperature in our model is negligible. In simple words: If we are at 4 pm today and want to predict the load in 1 hour for today, i.e., at 5 pm, the temperature (forecast) for 5 pm does not help a lot to improve the load forecast as the temperature information is hidden in the most recent demand observation at 4 pm, see e.g., Haben et al. (2019) for similar findings.

3.2 Augmenting structural breaks

Given the baseline model, we augment the time-varying intercept of the model by change-point components that allow for different types of structural breaks. This is:

i) a permanent change in the load level,
ii) a permanent change in the load level for the daily profile (e.g., a load reduction for only certain hours of the day),
iii) a permanent change in the load level for the weekly profile (e.g., a load reduction for only certain hours of the week).

These structural breaks are implemented using dummies for relevant time sets. We restrict the space of possible changes to all observations after 1 March 2020 which is before the coronavirus spread widely in Europe and issued the COVID-19 crisis in Europe. We estimate the model using lasso which is tuned by the Bayesian information criterion (BIC).

To analyse the results adequately, we estimate the model and then simulate from the estimated model 10000 times for the time range from 1 March 2020 onwards. This allows us to get other plausible paths of the effect. We regard the mean of the mentioned 10000 trajectories as the profile under the shutdown.

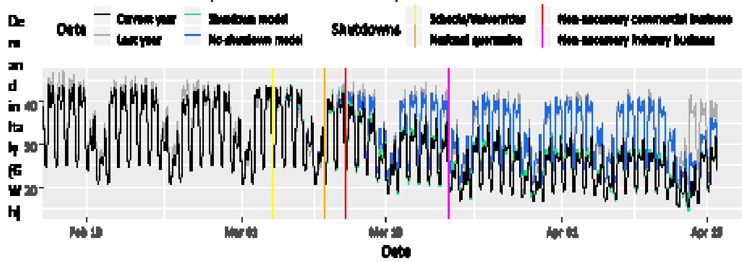

Figure 3: Electricity demand (GWh) in Italy during the ongoing pandemic compared to the models' and the last year's values. The vertical lines indicate shutdown dates.

We also simulate from the estimated model where we set all change-point effects to 0. This allows us to mimic a load situation without the COVID-19 shutdowns. Again, the corresponding average describes the profile that we want to compare.

Results

4.1 Demand in Italy

Figure 3 extends Figure 2 by adding the models' and previous year's curves . Let us note a very similar trajectory of the no-shutdown model to the last year's one. This indicates that the model is performing correctly. The only big inconsistency between these paths appears in the week starting on 13 April 2020. However, this is the week after the moveable Easter and thus a plausible public holiday effect.

Moreover, we observe that the current year's electricity demand started to deviate significantly from the no-shutdown model shortly after the third shutdown and it only deepened with the fourth one. The difference between the shutdown and no-

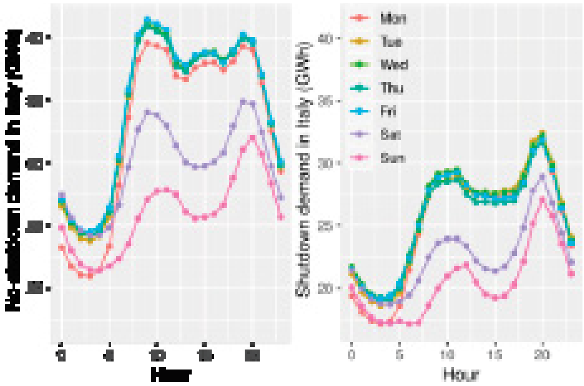

Figure 4: Weekly electricity demand (GWh) in Italy in the week starting on 30 March 2020 in a theoretical, no-shutdown case (left) and in the observed one (right).

shutdown models only confirms that the undertaken measures have heavily impacted the electricity load in Italy. Nevertheless, the seasonal effect is also present what is depicted by the slow decrease of the demand level of the model assuming no change-points. Hence, the shutdown effect is smaller than the naive comparison with pre-shutdown demand suggests. Another interesting aspect is that the structural change due to the shutdown of the non-necessary commercial business is quite smooth and requires a couple of days to settle at the corresponding load level. This suggests that after the mentioned shutdown some businesses were still running for a few days prior closing.

In Figure 4, we present a comparison of weekly demand over hours of the day between the theoretical, no-shutdown case and the observed that includes the shutdown effects. The plots can help to understand better the change in the weekly demand pattern as they are based on the week from 30 March to 6 April 2020, i.e., during the time of a significant impact of the shutdowns.

First, let us note the overall decrease of the load in the shutdown scenario. An interesting effect is the flattened morning peak (around 8 am - 12 am). This is most probably a result of many people working from home or not working at all and thus lesser utilization of production capacities, office building and electrified public transport, etc. Interestingly, the evening peak in demand is preserved and currently it is clearly the most electricity consuming part of every day in the week. This is reasonable as because of the lockdown, more people are cooking at home or using electricity-based entertainment. Furthermore, the difference in electricity demand between Saturday and Sunday shrank heavily due to the shutdowns.

Another interesting feature is that we see shifts of the morning load peak within the day. This is best visible on Sundays: usually at 7 am the load level would increase by about 2.5GWh (≈ 10% of the night load) from the night level. During the shutdown the increase starts later, at 7am we still remain at the night level load. A plausible explanation would be a 'getting up late'-effect. So the Italians tend to sleep longer during the lockdown period.

4.2 Demand in other European countries

Figure 5 presents the electricity demand in the

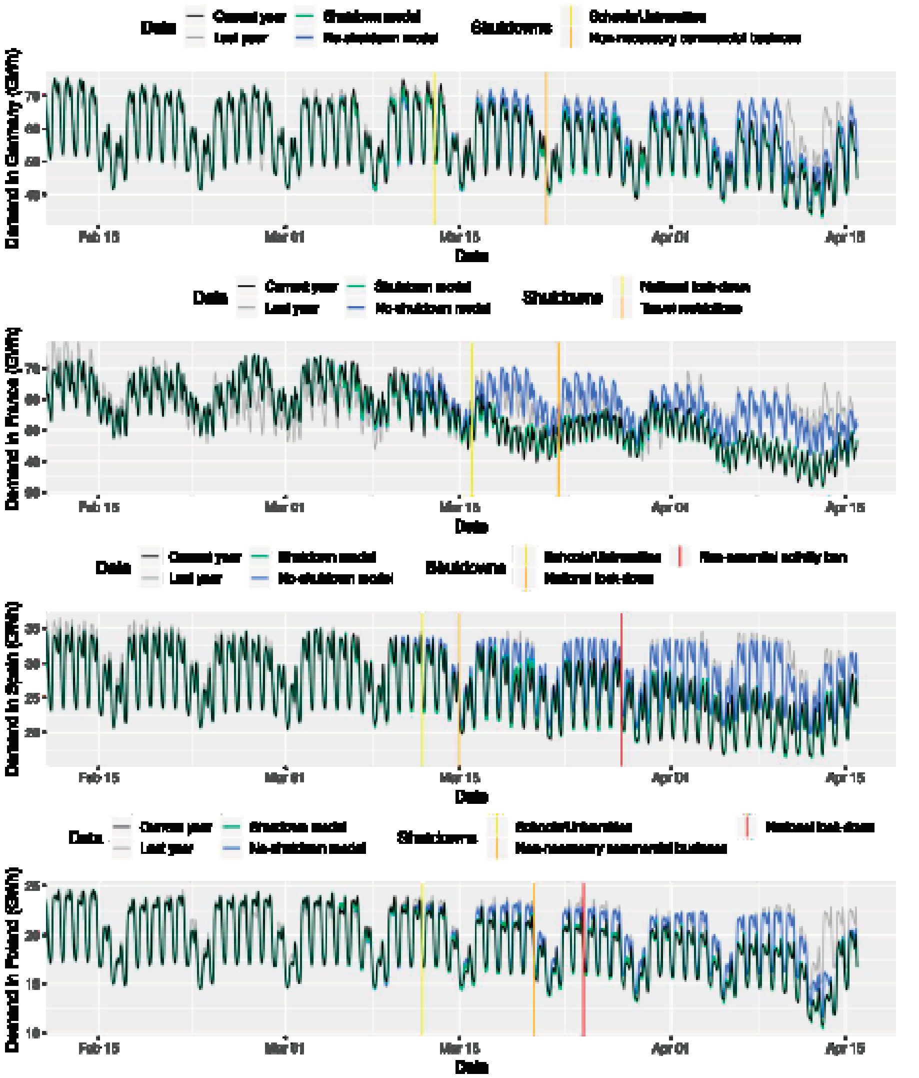

Figure 5: Electricity demand (GWh) in Germany, France, Spain and Poland during the ongoing pandemic compared to the models' and the last year's values. The vertical lines indicate shutdown dates.

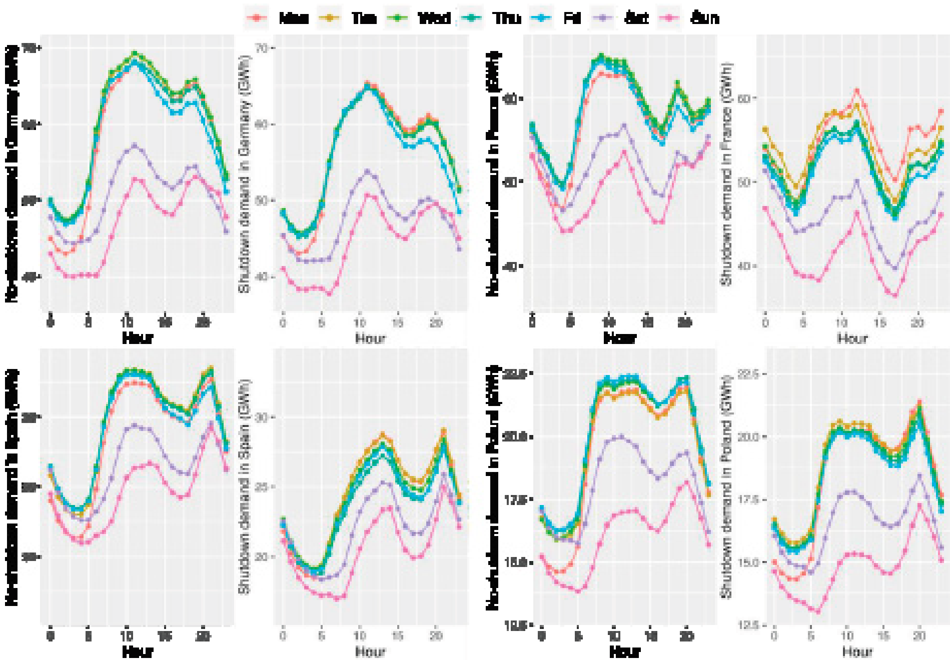

Figure 6: Weekly electricity demand (GWh) in Germany, France, Spain and Poland in the week starting on 30 March 2020 in a theoretical, no-shutdown case and in the observed one.

other considered countries: Germany, France, Spain and Poland. The overall pattern of the rising deviation between the shutdown and no-shutdown models is similar to the one in Italy, but respectively delayed. However, the level of the deviation differs among the states, what was already depicted in Figure 1. Interestingly, in France we observe an impact of the shutdowns before they went live. The reason may be that the limitations were announced accordingly earlier and the residents and companies of France may have started changing their public activity earlier, following the other countries' recommendations. Furthermore, even before the national lock-down all big events, football matches etc. were being cancelled. However, there might be interactions with the export of electricity (esp. to Italy) and temperature effects. Concerning the latter, the period from 21 March to 2 April was relatively cold in Europe, and France has a high temperature dependency in the electricity demand due to large electric heating capacities.

Figure 6 shows the comparison of weekly demand over hours of the day between the shutdown and no-shutdown scenarios for Germany, France, Spain and Poland. Again, the plots are based on the week from 30 March to 6 April 2020. Similarly as in the Italian case, we observe an overall demand decrease for every country. Let us note that except of the level change, the weekly demand pattern remained almost the same in Germany. On the other hand, in France, Spain and Poland the flattening of the morning peak and preserving the evening peak are present similarly as in Italy. This can be also explained by lesser activity in the morning connected to the professional life and remained or even higher activity in the evening due to entertainment. The 'getting up late'-pattern is also visible in all the considered countries. Still, it is most distinct in the Mediterranean countries: France and Spain.

Conclusion

The shutdowns introduced due to the COVID-19 pandemic have impacted significantly both the level of the electricity demand in Europe and its weekly pattern. The revocation of the shutdowns and the end of the pandemic should in theory slowly turn back the electricity demand to the pre-pandemic volumes. However, in practice it may appear that the pandemic has made a permanent influence on the behavioural patterns.

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The Impact of COVID-19 on Transport Demand, Modal Choices, and Sectoral Energy Consumption in Europe

BY GIACOMO FALCHETTA AND MICHEL NOUSSAN

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Current trends in transport demand amid COVID-19

A cluster of pneumonia of unknown origin was identified in Wuhan, China, in December 2019. Since then, the related disease (COVID-19) has spread in most world regions[1]. As of mid-April 2020, Europe is the continent with the highest number of reported cases and fatalities[2]. Disease spread containment policies have locked most of the population at home[3] – albeit with fragmented responses by countries –, bringing significant repercussions on the demand and supply for services.

One of the most rapidly impacted sectors is the transport sector, and chiefly passenger mobility. Time-series from mobile phone location data suggest that urban transport demand has plunged[4,5] (Figure 1), while a recent aviation report[6] reveals that commercial flight operations have fallen dramatically worldwide, with over two thirds less flights than in the same period of 2019. Another report by a mobility-as-a-service provider[7] highlights declines of public transit usage (compared to the pre-COVID period) of about 90% in Italy and France, 85% in Spain, 75% in the United Kingdom and 70% in Germany, with some variability across cities. Overall, a generalised heavy contraction of the passenger transport demand is observed worldwide and mode-wide, although with some heterogeneity. Freight transport is also being affected in different ways by COVID-19: while supply chains are being discontinued due to factory shut-downs, a robust increase in home deliveries is being experienced[8].

In the last years the transport sector was responsible for a quarter of total greenhouse gas emissions, and it consumed alone almost 60% of the total global oil demand[9]. A strong halt in the demand and supply for transport services will thus be directly responsible for a severe decline in the demand for energy products consumed by the transport sector throughout 2020 and beyond. These dynamics are however not linear, because they imply a transformation of the available supply options as well as the consumer preferences affecting transport modal shares. Amid the concrete risk that a universal vaccine coverage will not be reached before mid-2021[10], it is meaningful to discuss what challenges decision-makers in the transport sector will need to face, and how these can be addressed in ways that are not detrimental to the global energy markets, environmental pollution, and the greenhouse gas emission reduction targets that are in place.

In this commentary we discuss how these complex dynamics might shape the final energy consumption in the transport sector over the short and longer runs through their impact on both the final transport demand and mode choice decisions, with a particular focus on urban environments in European countries, where public and active mobility often displays high usage rates.

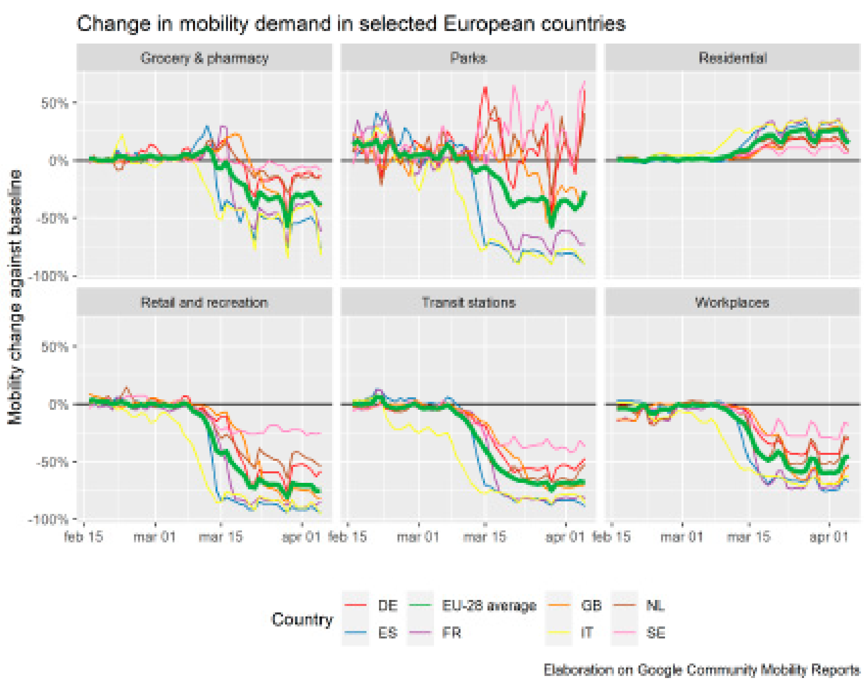

Figure 1: Total mobility demand change (Google estimate) in selected European countries, by journey destination.

Potential long-run impacts on total travel demand

The duration of the current lockdown is challenging to estimate. On top of the present uncertainty, it is possible that additional virus waves will hit different countries, resulting in additional measures of travel restriction in the future. While this situation is causing severe health, social and economic issues to the population, it may also offer people and companies the opportunity of evaluating alternative ways of living and working. For instance, by experiencing everyday routines that are far from what considered "normal" only few months ago.

A large share of the European population is experiencing the opportunities and the challenges of teleworking. The lessons learnt from this involuntary experiment may prove useful in implementing permanent solutions to cut costs and optimize workers' life balances, and therefore companies' productivity. While numbers are challenging to estimate, experts agree that the use of telework will significantly increase even after the end of the emergency[11]. This regular travel demand contraction will mostly be experienced in rush hours, with benefits on environmental pollution as well as on urban congestions.

In parallel to teleworking, people are also increasingly relying on home deliveries, resulting in a shift from the mobility of people going for shopping towards last-mile freight delivery. The COVID-induced lockdown is accelerating a trend that was already rising in the last decade, with customers getting used to the benefits of waiting at home for the goods and services that they purchase. This may result in an overall increase in freight transport demand, but delivery companies may still have room for improving the efficiency of their logistics.

It is however the crisis caused by this worldwide halt of industrial supply chains that will likely exert the largest impact on global transport demand, with huge impacts on the globalized economic system. Companies may reorganize their structure giving priority to resilience, due to the fragility of global supply chains both against the pandemic and the ongoing trade war between China and the U.S. Some companies may strengthen local supply chains, especially in specific sectors, possibly supported by governments. These choices may hamper a quick rebound of the economy, with strong consequences on international freight transport.

Finally, the crisis may have a similar adverse impact on international travel for leisure. Tourism is one of the sectors that have been hardest hit by the current emergency. While many companies will likely promote low-cost offers to try to trigger a quick recovery of the tourism demand, especially in areas where this represents a large share of the economy, recovering people's interest for international travelling will not be obvious. For months people might decide to minimise the risk of getting infected while also reducing their unnecessary expenses to cope with the harsh economic situation. In addition, tourists might decide to support national or local businesses by shifting their preferences away from international travelling, at least in the medium-run.

Potential long-run impacts on modal shares

In addition to the passenger-kilometre demand, the final energy demand depends on the shares of modes chosen to meet such demand. COVID-19 is an airborne, highly infectious disease, which is likely to proliferate in human-dense environments including light rail, buses, trains, and planes. Therefore, a social stigma towards the use of these transport option is likely to last also when social lockdown measures will be relaxed over the next months. This attitude is likely to have a pervasive impact on both the modal choice of individuals and on how commercial transport companies shape their offer. Transit is already the modal choice that is seeing a stronger decrease across European countries (Figure 2), and mostly where lighter travel restrictions have been imposed, such as in the Netherlands and Sweden, where people are preferring other transportation modes. This tendency is likely to persist in the months after the end of the emergency.

For instance, many may revert to car commuting, irrespective higher private costs. Conversely, carpooling trips might fall significantly, especially when organized with strangers via online platforms. At the same time, strong impacts on ride-hailing and car-sharing companies business models are expected. The negative social effects will be particularly hard in urban mobility at peak hours, since in many cities congestion was already a problem even with a significant modal share of public transport. The increased use of private vehicles may often compensate the demand decrease triggered by teleworking.

Because of these dynamics, substantial public funding will be required in support to public transport, which will face a strong decrease in ridership and revenues, but it will still need to ensure an acceptable level of service for people that cannot afford a private transport mode. Besides crowd-out from transit to private vehicles, active mobility may prove to be a viable alternative for public transportation in cities. This shift would however require strong policy actions that support the deployment of the necessary infrastructure that allow people walking and biking in safety.

Long-run repercussions for transport energy consumption and emissions

The combined effect of the evolution of transport

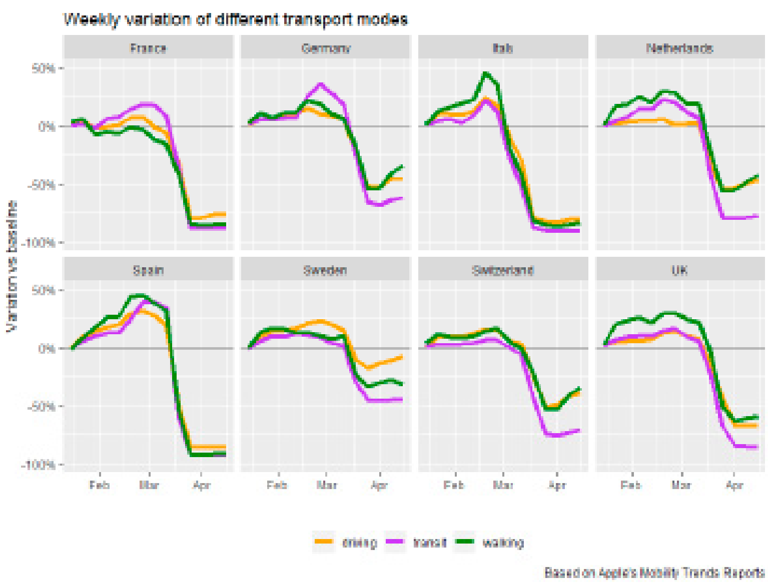

Figure 2: Estimated mobility demand change in selected European countries, by transport mode (Authors' elaboration on Apple data).

demand and modal share will shape the energy consumption of the transport sector. It is early to speculate about which of these two trends will dominate over the other, but this trade-off might also differ across countries and cities. Moreover, further shocks may play an additional role. For instance, in an attempt to support the recovery of automotive industries, some countries may loosen the environmental standards for new cars (like recently observed in the United States[12]). These political decisions might have repercussions over the long-run, depending on the average lifetime of new vehicles. The economic crisis may also result in a slower renewal of the vehicle fleets, with older, more energy-consuming and polluting vehicles being used for longer time before being replaced by newer models.

In addition, it is important to underline that in some contexts, energy consumption will not be linearly correlated with transport demand. In some transport segments, such as long-haul aviation, a lower demand may result in lower load factors rather than lower flights, depending on the complex economics and regulations: in some cases, companies are forced to operate empty flights to avoid losing flight slots (just like what happened in Europe few weeks ago[13], although now this rule has been temporary suspended). Regulation and rules will require to be revised to be more resilient and avoid such backlashes.

To add a further level of complexity, the evolution of oil prices may represent an additional aspect impacting the energy demand in transportation. Low oil prices (as witnessed in the first quarter of 2020) may support a recovery of international transport operations, such as aviation and shipping, while also delaying investments on energy efficiency and better performance of transport modes. On the other hand, it is not clear how long the current prices will last, depending on the ability of oil producers to reach and maintain a deal on scheduled production rates.

Conclusions and policy implications

Overall, our discussion suggests that high uncertainties characterise the longer-run impacts of COVID-19 on energy demand from the transport sector. This is because the supply and demand sides are each reacting in complex ways, with a prominent role of digital telecommunications in reducing the need for transport of people.

Our key conclusion is that passenger transport demand will remain lower than a counterfactual case of no-COVID19 beyond year 2020. The main reasons are an increase of the role of teleworking and a decrease of international travel, especially for leisure. Yet, we argue that if properly channelled by policy and investment, this transformation might become structural and persist even when the global economy will recover. There is in fact large potential for learning from the current “living lab” that different solutions exist and work well if properly deployed. COVID-19 is also offering an unprecedented opportunity of learning to further improve solutions (e.g., better organization and planning instead of emergency, for teleworking, e-commerce, etc.). Still, an adverse side-effect of the current economic recession is likely to be the lower investment in new and clean vehicles, resulting in an overall lower improvement of the efficiency of the fleets, both for personal private transport and for freight transport.

What remains more uncertain is the pace at which freight transport demand will recover, since it will depend on the duration of the economic crisis and on the strategic choices of companies and governments to develop more resilient supply chains, in particular in specific sectors.

On the policy side, a relevant question is if there will be the need of supporting local municipalities, which will face the challenge of lower revenues (including those from parking fees, highway tolls, etc.) but with the same operational expenses (road maintenance, etc.). The same is true for transport companies, which are facing lower revenues for ridership with the need of avoiding cutting service levels. It is of crucial importance that public authorities ensure equal access to transport, invest on resilient infrastructure (factoring in also environment and health externalities), especially supporting active mobility. Building on the opportunity of triggering an increased use of active transportation when possible is likely to provide people with the experience of a new mobility paradigm that may remain after this crisis, with strong impacts on future energy demand and pollution

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The Impact of COVID-19 Restrictions on Electricity Demand: Evidence from Two Jurisdictions

BY JAMES CARROLL, KENNETH CONWAY, ALASTAIR SHANNON AND ELEANOR DENNY

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Covid-19 has radically changed lives across the globe over a very short period of time. Extensive quarantine measures imposed by governments have resulted in households spending considerably more time at home and many businesses reducing or ceasing operations. This short article explores the impact of COVID-19 restrictions on electricity demand levels across two separate but related jurisdictions, the Republic of Ireland (IE) and Northern Ireland (NI). This is an interesting case study as, while both areas are geographically located on the same island and are part of the same electricity market, they have separate governments and imposed COVID-19 restrictions at different times. Furthermore, at the time of writing (April 14th), mortality rates are identical across jurisdictions (74 deaths per million citizens) and both are generally showing declines in rates of daily increase.

In the Republic of Ireland (IE), the first confirmed case of COVID-19 was on February 29th 2020. In the subsequent two weeks, a small number of new cases emerged and some large businesses (for example Google) voluntarily requested that their staff work from home. On March 12th, The Taoiseach (Irish Prime Minister) announced the closure of all educational and childcare

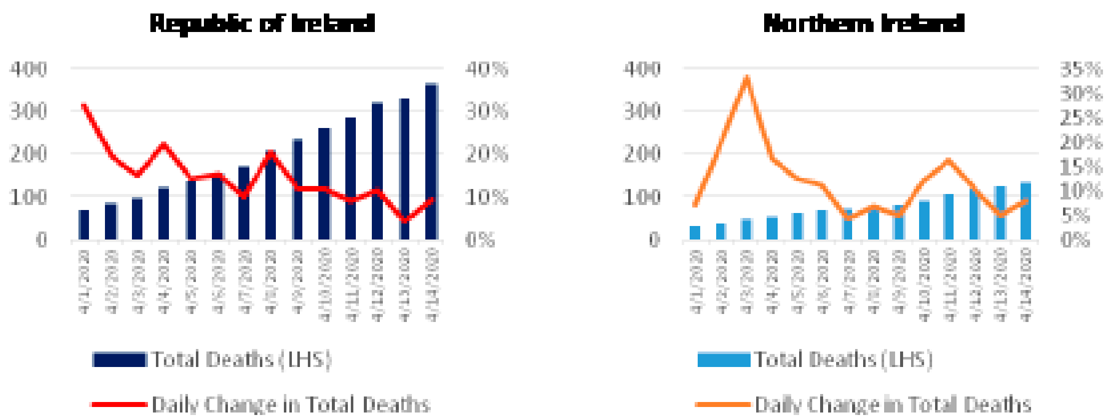

Figure 1: COVID-19 Cumulative Deaths and Daily Percentage Change, April 2020
Source: own calculations based on data from the Public Health Agency (Northern Ireland) and the European Centre for Disease Prevention and Control

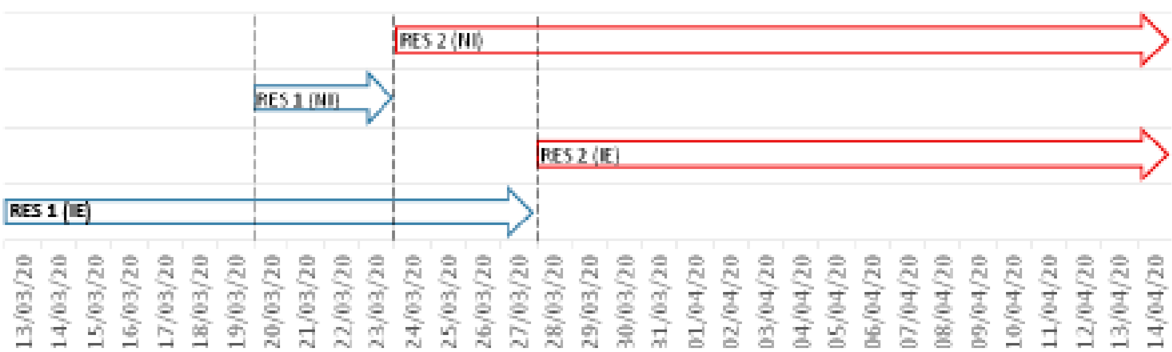

Figure 2: COVID-19 Timeline for Moderate Restrictions (RES 1) and Heavy Restrictions (RES 2) in the Republic of Ireland (IE) and Northern Ireland (NI)
Source: author's design

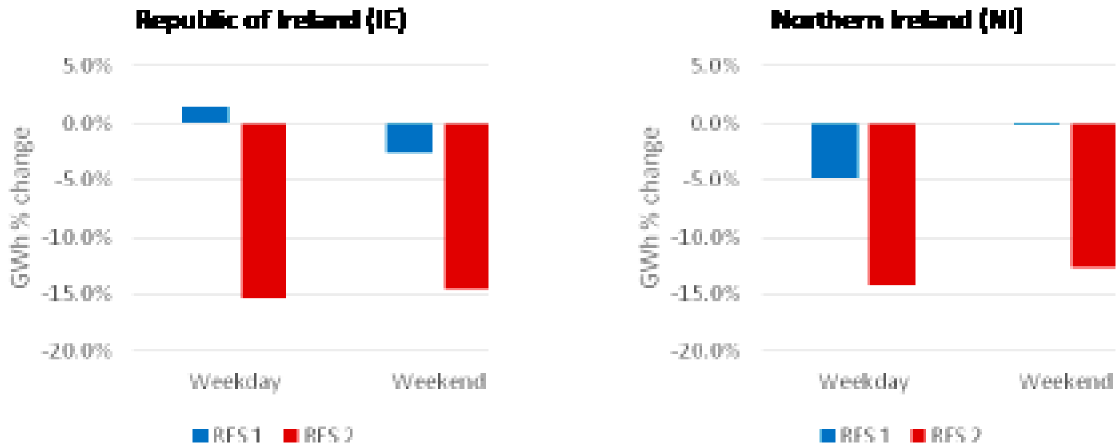

Figure 3: Reduction in Average Daily Electricity Demand (GWh) in the Republic of Ireland and Northern Ireland due to COVID-19 Restrictions

Source: created using *EirGrid* 15-minute interval data from April 1st 2018 to March 31st 2020

Notes: estimates are based on separate OLS regressions using daily totals from IE and NI on weekdays and weekends (includes public holidays). Baseline is the period from 1st April to the start of restrictions. Regressions control for mean temperature and also include month dummy variables to capture long-term trends. In IE, RES 1 refers to the period from March 13th to March 27h and RES 2 refers to March 28th onwards. In NI, RES 1 refers to the period from March 20th to March 23h and RES 2 refers to March 24th onwards

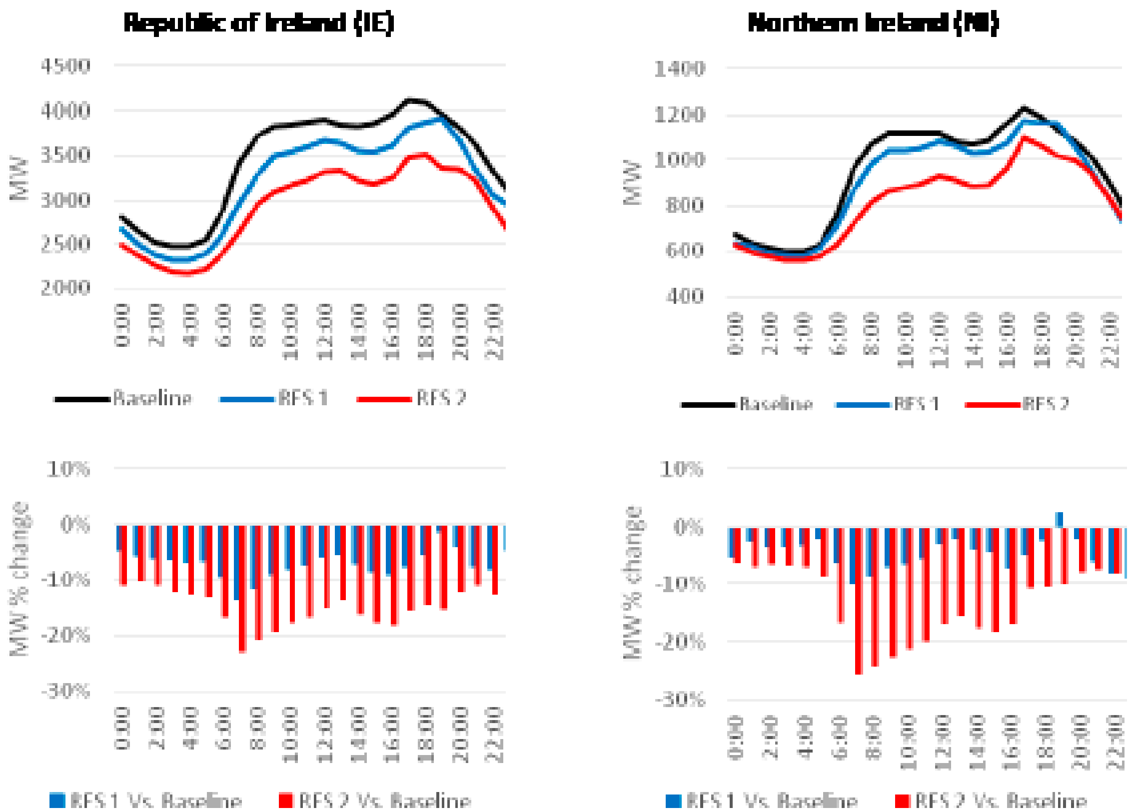

Figure 4: Average Weekday Hourly Electricity Demand (MW) in the Republic of Ireland and Northern Ireland, Pre- and Post-Movement Restrictions

Source: Created using EirGrid 15-minute interval data from April 1st 2018

Notes: estimates are based on separate OLS regressions using hourly totals from IE and NI on weekdays and weekends (includes public holidays). Baseline is the period from 1st April to the start of restrictions. Regressions control for mean temperature and also include month dummy variables to capture long-term trends. In IE, RES 1 refers to the period from March 13th to March 27h and RES 2 refers to March 28th onwards. In NI, RES 1 refers to the period from March 20th to March 23h and RES 2 refers to March 24th onwards facilities, the cancellation of large gatherings and advised a high degree of caution with regard to international travel. In the analysis that follows, this period of moderate restrictions is labelled 'RES 1'. From March 28th, all citizens were required to stay at home in all circumstances except for essential workers travelling to work, to shop for food or medicine and for brief individual exercise within a 2km radius of home. This period of severe restrictions is labelled 'RES 2' below.

In Northern Ireland (NI), COVID-19 restrictions were initially determined by the decisions of the UK Government in Westminster. The first confirmed case of COVID-19 was on February 28th 2020 and widespread restriction measures were implemented on 20th March which included the closure of schools, bars, restaurants and other social venues (RES 1). More severe restrictions (RES 2), similar to those applied in IE, came into effect four days later, on the evening of March 23rd.

Figure 3 describes the effects of these restrictions on mean daily weekday and weekend (includes public holidays) electricity demand. In IE, the period of moderate restrictions (RES 1) did not lead to a decline during weekday but a slight decrease on weekends (2.5%). However, following more severe restrictions from March 24th (RES 2), average daily demand (GWh) is down about 15% on both weekdays and weekends. Similar patterns are evident in NI, with large reductions mainly during the RES 2 period – 14% on weekdays and 13% on weekends (note that RES 1 in NI only covers four days: two weekdays and two weekend days).

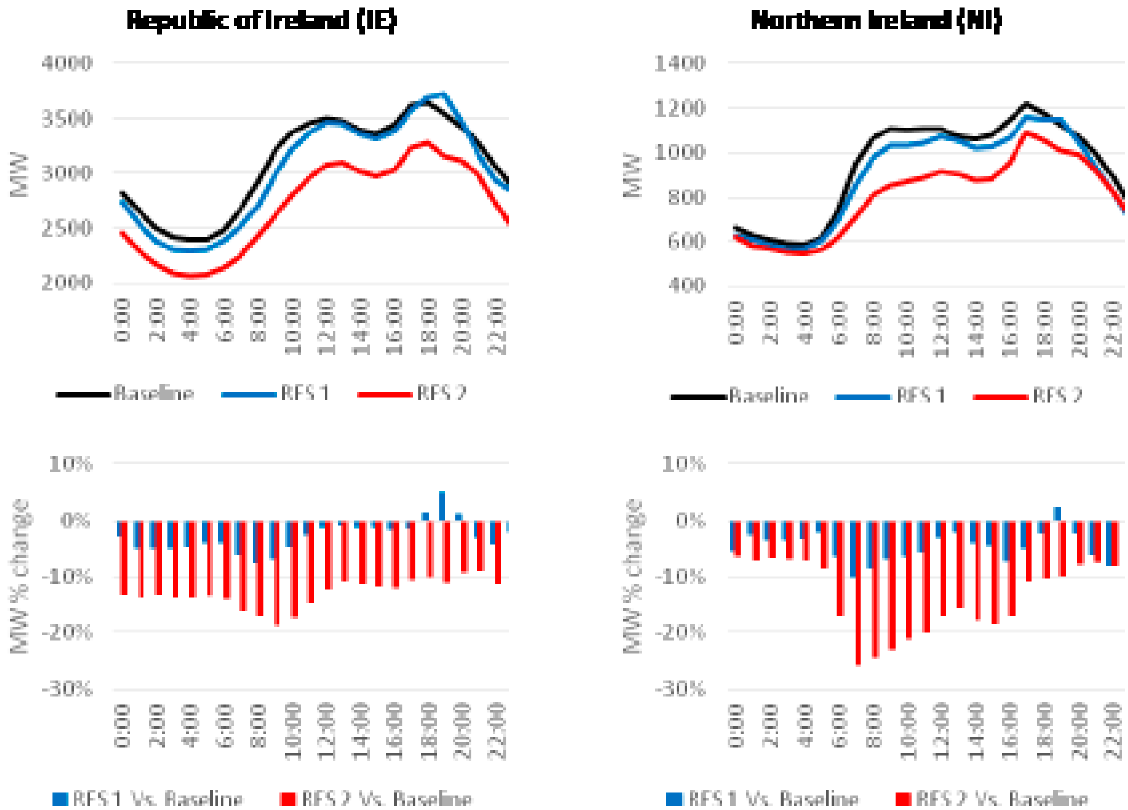

Figure 5: Average Hourly Weekend/Public Holiday Electricity Demand (MW) in the Republic of Ireland and Northern Ireland, Pre- and Post-Movement Restrictions

Source: Created using EirGrid 15-minute interval data from April 1st 2018

Notes: estimates are based on separate OLS regressions using hourly totals from IE and NI on weekdays and weekends (includes public holidays). Baseline is the period from 1st April to the start of restrictions. Regressions control for mean temperature and also include month dummy variables to capture long-term trends. In IE, RES 1 refers to the period from March 13th to March 27h and RES 2 refers to March 28th onwards. In NI, RES 1 refers to the period from March 20th to March 23h and RES 2 refers to March 24th onwards

Figure 4 presents changes in weekday hourly demand for both jurisdictions. It should be noted that during the period of the COVID-19 restrictions the clocks also changed by +1 hour which brings with it a changed evening shape, with the evening peak being split into two 'cooking' and 'lighting up' peaks. As the evenings are much longer, domestic and street lighting aren't needed until later. Notwithstanding the clock change, COVID-19 related declines observed above were not evenly spread across the day. The largest change is observed in the morning profile, with a less steep rise towards the morning peak. This is likely due to more people working from home and having more staggered waking times with no commute and schools being closed. This is particularly the case for RES 2, and is also more pronounced in NI. Also of note is the changed evening peak profile during RES 1 – in both jurisdictions, the evening peak lasted longer.

For weekends and public holidays (Figure 5), different profile changes are observed across both jurisdictions. The most striking change in NI weekend consumption is the flatter demand growth during the morning and a new morning peak during both RES 1 and RES 2 periods, which is now closer to midday. As with weekdays, the shape of the evening peak has changed on weekends during RES 1, which is more prolonged and later in the day.

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Electricity Markets Under Lockdown: Insights From New York

BY DAVID BENATIA

Introduction.

Three billion people are under lockdown. Many regions across the globe have taken drastic measures in an effort to contain the outbreak of COVID-19. Restaurants, bars, schools, universities as well as many commercial and industrial operations considered as non-essential have shuttered. Travel bans have been enacted and borders have been closed. In early April 2020, the economic and social consequences of the "Great Lockdown" only start to unravel as millions of workers file jobless claims.

The short- and long-term impacts of containment measures on electricity markets, although sizeable, are not as dramatic as for the rest of the economy. As teleworking becomes the new normal and a large share of economic activities are on pause, many electricity systems experience unusual patterns of consumption and coincidentally low wholesale prices. Lockdown measures are causing unprecedented reductions of electricity demand ranging from up to 15-20% in France (RTE, 2020), down to only 2% in Texas (ERCOT, 2020). Those large sudden variations are unparalleled in history, even during major economic crises.

At the epicenter of the crisis in the U.S., the New York state's electricity market is likely to be the most affected in North America. This article documents the impacts and consequences of the COVID-19 crisis on the New York electricity market using a simple yet powerful machine-learning approach to causal inference (Benatia and de Villemeur, 2019).

Based on this methodology, the New York state is found to have experienced a 7.5% electricity demand reduction since the beginning of lockdown on March 22, 2020. New York City (NYC) is the most affected area with a 12% reduction. Morning peaks have decreased by 17% in NYC and daily consumption patterns have considerably changed. Interestingly, the effects of sheltering measures on daily consumption are qualitatively similar across regions (RTE, 2020).

Additional findings reveal that load forecast errors have surged during the first weeks of containment measures. Over-forecasting results in inefficient daily system operations because of additional operating costs from unnecessary start-ups and provisions of spinning reserves (Ortega-Vazquez and Kirschen, 2006). This article shows that short-term forecasting models have adjusted to new load patterns within a couple of weeks. Around the globe, system operators have mobilized their workforce to attenuate forecast errors. (NYISO, 2020; RTE, 2020).

Finally, wholesale prices have dropped by 50% since the beginning of the lockdown. This reduction is mainly attributed to low fuel prices rather than unexpectedly low demand levels. The main reason is that unexpected load reductions have been offset by the phasing-out of a nuclear power unit. Polluting emissions have hence remained stable.

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See footnotes at end of text.

Load forecasting, neural networks and causal inference. The New York electricity system operator (NYISO) uses a combination of advanced neural network and regression type models for load forecasting (NYISO, 2019). This algorithm feeds on weather forecasts and recent load realizations to predict hourly electricity demand in each of the 11 load zones for the following days. The algorithm proves to be reliable with a 3% mean relative absolute error for day-ahead forecasts over the period 2013-2020.

Our modelling approach consists in training a neural network capable of predicting the hourly load for each zone under business-as-usual conditions, but without relying on recent load realizations or other endogenous variables affected by lockdown measures. The objective is to construct a reliable counterfactual electricity demand assuming containment measures had not been enacted for the entire lockdown period. The discrepancies between the model's predictions and the actual realizations have a causal interpretation as the effect of containment measures on electricity consumption. The advantage of this method is to be able to credibly perform causal inference and obtain standard errors for the mean effects of interest.

The model, hereafter denoted N-Net, has a set of 302 predictors, all exogenous to lockdown measures. The set includes hourly weather conditions, such as temperature, humidity, and wind speed measures from 19 weather stations in New York state (source: https://www.wunderground.com), the West Texas Intermediate crude oil prices (source: St-Louis Federal Reserve), spot natural gas prices from Henry Hub, New York, and Chicago (source: Energy Information Agency), two-months lagged load realizations, and time fixed-effects for hour of the day, day of the week, and month of the year. The algorithm has a single-hidden layer with 5 neurons. It is trained in a few minutes using a randomly selected training sample with 70% of the 60,207 hourly observations for the period 2013-2020 prior to school closures in NYC on March 16, 2020. The remaining observations are randomly split into a validation (20%) and testing (10%) datasets.

Table 1 reports the performance of N-Net and the day-ahead forecasts used by NYISO to predict hourly electricity consumption. Performance is measured using the Root-Mean-Squared Prediction Errors (RMSPE). Its values on the test set, e.g., 428.6 for total NYISO demand, provides a good measure

Table 1. Forecasting performance (RMSPE): N-Net vs NYISO Day-ahead

	Test set		School closures 03/16 - 03/22		Lockdown 1 03/23 - 03/29		Lockdown 2 03/30 - 04/05		Lockdown 3 04/06 - 04/12	
Zone	N-Net	NYISO	N-Net	NYISO	N-Net	NYISO	N-Net	NYISO	N-Net	NYISO
Capital	55.5	74.5	81.9	35.4	77.6	75.0	68.6	50.3	74.8	49.2
Central	63.4	110.7	121.3	43.5	170.6	73.7	128.5	63.1	144.7	82.2
Dunwoodie	30.8	31.5	36.5	17.9	38.5	28.5	32.8	28.1	55.4	24.8
Genessee	42.2	58.6	40.9	27.2	58.6	45.0	54.0	45.6	50.8	38.9
Hudson Vall.	44.5	64.6	67.7	29.3	75.2	74.4	65.6	43.6	73.5	38.5
Long Island	79.6	87.7	78.2	74.8	135.4	145.0	106.0	84.7	113.4	97.4
Mohawk Vall.	50.7	147.3	149.0	101.4	154.6	109.2	90.8	106.3	49.9	145.5
Millwood	27.9	27.5	26.9	24.5	33.6	22.8	49.5	18.9	47.5	21.6
NYC	142.3	154.8	365.2	272.4	597.2	349.3	702.2	397.1	751.7	315.9
North	26.0	24.5	37.9	28.1	28.1	30.3	28.4	30.9	33.6	23.6
West	69.2	76.9	79.0	42.4	128.9	49.4	128.8	57.6	126.2	60.2
NYISO	428.6	665.9	951.6	325.5	1397.4	695.3	1309.9	587.5	1311.5	578.9

Note: This table reports performance in terms of Root-Mean-Squared Prediction Errors (RMSPE) of the model (N-Net) versus the day-ahead forecasts used by NYISO. The test set contains 3500 randomly selected observations that were not used to train or validate the model. The last row reports the total load in NY.

of the extent to which the model generalizes to new data. N-Net is found to outperform NYISO forecasts with an average relative absolute error below 2%. Part of this is due to the fact that N-Net is based on actual weather conditions rather than weather forecasts. Nevertheless, it shows that the model performs

Table 2. Weekly electricity consumption reductions (GWh)

Zone	Week before 03/05 - 03/15	Schools closure 03/16 - 03/22	Lockdown 1 03/23 - 03/29	Lockdown 2 03/30 - 04/05	Lockdown 3 04/06 - 04/12
Capital	-3.9	-10.4	-7.6	-8.1	-8.9 (2.7)
Central	-8.1	-17.0	-28.3	-18.9	-22.0 (3.2)
Dunwoodie	-1.3	-3.2	-2.6	-3.1	-7.8 (1.6)
Genessee	0.2	1.6	-6.3	-4.4	-3.8 (2.0)
Hudson Val.	-1.2	-4.4	-4.6	-7.0	-7.8 (1.9)
Long Island	-1.7	-4.2	-8.3	-9.8	-11.6 (3.6)
Mohawk Val.	-14.1	-23.3	-24.7	-11.9	-6.5 (2.7)
Millwood	-7.1	-3.8	-4.0	-7.8	-8.8 (1.4)
NYC	-11.9	-56.2	-90.7	-105.5	-113.8 (7.2)
North	-3.1	-4.6	-3.9	-3.6	-6.2 (1.3)
West	2.3	-9.0	-18.0	-18.0	-17.9 (3.6)
NYISO	-53.9	-141.1	-211.6	-194.5	-193.2 (15.4)

Note: This table weekly consumption changes per zone in GWh. Standard errors are reported in parentheses in the right-most column. NYISO denotes the total load in New York state.

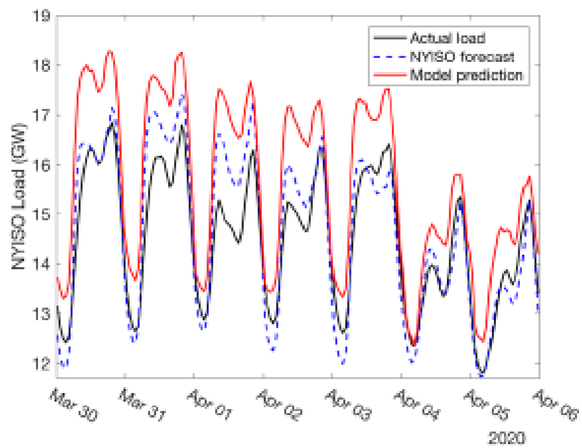

Figure 1. Actual load (black), day-ahead forecast (blue) and counterfactual load (red)

accurately, without relying on recent load realizations. This table also shows that NYISO forecast errors have increased temporarily during the first weeks of containment measures. The forecast algorithm has quickly adapted since then as errors have reduced in the third week of lockdown.

As an illustration, the actual NY total load (black line), the NYISO forecast (dashed blue line) and the N-Net counterfactual load (red line) are shown in Figure 1 for the second week of lockdown (March, 30 to April, 5). The deviations between the actual load and the NYISO forecast does not reveal large consumption reductions. However, the discrepancy with respect to the counterfactual load identifies a sizeable effect of lockdown measures during the entire week.

Weekly electricity consumption reductions. Weekly demand reductions are estimated as the aggregated differences between actual demand and its counterfactual in the absence of containment measures over the course of each week. Table 2 reports the estimated weekly demand reductions (in GWh) separately for each zone during the week before schools closure and the following four weeks. Standard errors are reported in parentheses in the right-most column.[1] The load reduction during the week preceding any official measure is estimated at less than 2% for the entire state (-53 GWh). The purpose of schools closure, enacted on March 16, is to induce parents to stay home. It has resulted in a 6.3% (-56 GWh) decrease in NYC and 5.1% (-141 GWh) statewide. Finally, electricity demand under lockdown is found to be 10-13% smaller than usual in NYC and 7-8% smaller statewide. Interestingly, there are zones such as Long

Table 3 Estimated relative change in daily load (percentage) under lockdown (weekdays)

Table 1. Estimated relative change in daily load (percentage) under lockdown (weekdays)

Zone	Night		Morning		Afternoon		Evening	
Capital	-0.02	(.04)	-0.07	(.03)	-0.04	(.05)	-0.02	(.04)
Central	-0.07	(.03)	-0.10	(.03)	-0.09	(.03)	-0.09	(.03)
Dunwoodie	0.01	(.05)	-0.08	(.04)	-0.06	(.05)	-0.05	(.05)
Genessee	-0.03	(.03)	-0.07	(.03)	-0.04	(.04)	-0.02	(.04)
Hudson Val.	-0.01	(.04)	-0.08	(.03)	-0.07	(.04)	-0.02	(.04)
Long Island	-0.03	(.03)	-0.07	(.03)	-0.03	(.04)	-0.03	(.03)
Mohawk Vall.	-0.09	(.05)	-0.11	(.05)	-0.12	(.05)	-0.10	(.05)
Millwood	-0.13	(.06)	-0.14	(.06)	-0.09	(.09)	-0.12	(.07)
NYC	-0.07	(.02)	-0.17	(.02)	-0.16	(.02)	-0.12	(.02)
North	-0.05	(.04)	-0.05	(.04)	-0.04	(.04)	-0.03	(.04)
West	-0.06	(.03)	-0.11	(.03)	-0.07	(.04)	-0.07	(.04)
NYISO	-0.05	(.02)	-0.11	(.02)	-0.09	(.02)	-0.07	(.02)

Note: This table weekly consumption changes per zone in GWh. Standard errors are reported in parentheses in the right column. NYISO denotes the total load in New York state.

Island or Capital where the effects of those measures have been much more limited (less than 4%). Part of

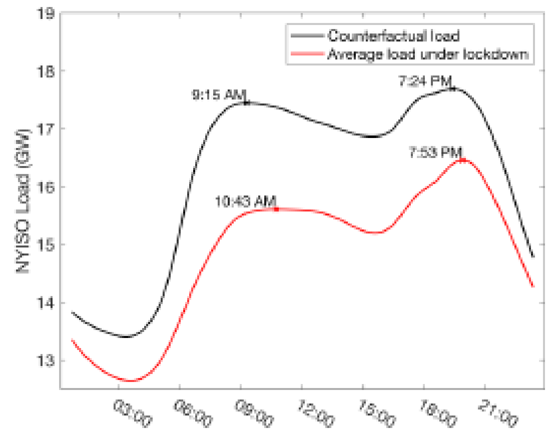

Figure 2. Average load pattern under lockdown (weekdays

this finding is explained by New Yorkers fleeing to less densely inhabited areas.

Changes in daily load patterns. New daily load patterns have been observed in all regions under lockdown. Table 3 reports the average estimates for the three (first) weeks of lockdown in New York. Each value is the estimated average relative changes in electricity demand during night hours (10 pm to 6 am), morning hours (6 am to 12 pm), afternoon hours (12 pm to 6 pm) and evening hours (6pm to 10 pm). Standard

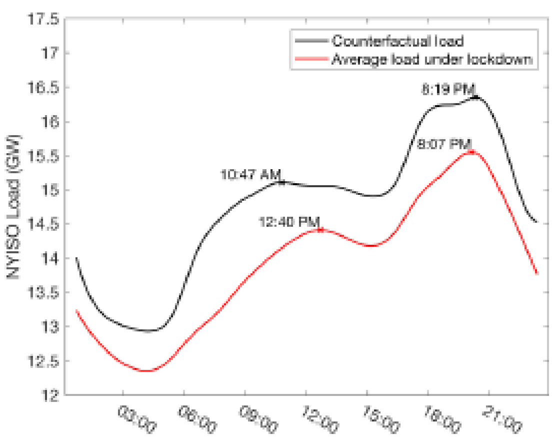

Figure 3. Average load pattern under lockdown (weekends)

errors are reported in parentheses.[2] The main finding is an attenuation of morning demand, down by 17% in NYC and 11% statewide. This effect is found to be statistically significant in nearly all zones. Reductions during other hours are relatively smaller. In many areas, such as Long Island, the afternoon consumption level under lockdown is not found to be significantly different than usual. The effect of schools closure is smaller, with an attenuation of morning demand of about 8% in NYC and 5% statewide.

Sheltering measures have also affected consumption timing. Figure 2 shows the daily load for weekdays averaged over the lockdown period (in red) and the average counterfactual load (in black), had lockdown measures not been enacted. The morning peak turns out to be much flatter and reaches its maximum 1.5 hours later. This pattern bears resemblance with what is usually observed during a widespread snow day (NYISO, 2020). Those changes are driven by increased demand from residential consumers and reduced commercial energy use. This finding may also suggest that lockdown measures affect sleeping patterns.

Figure 3 shows the average daily load and its counterfactual during weekends. The morning peak is deferred by nearly 2 hours due to lockdown measures. This finding is suggestive of the large reduction in economic activities during weekends and possibly modified sleeping patterns. E[4]vening consumption increases more gradually and decreases less sharply after the peak.

Limited short-term consequences. Although unprecedented, those changes in electricity demand do not have far-reaching short-term implications for electricity markets. The discussion in this section is based on findings obtained using a similar methodology.

Forecast errors have been larger for 2 to 3 weeks. Learning algorithms take some time to adjust to new load patterns and manual adjustments are required to prevent systematic deviations. The market data from NYISO do not reveal statistical significant increase prices for ancillary services. The economic consequences of forecast errors have hence been limited.

In New York, day-ahead and real-time prices have decreased from around \$30/MWh to \$15/MWh coincidentally with demand reductions caused by the lockdown. \$30/MWh corresponds to the median price whereas \$15/MWh is around the 5th percentile. Nevertheless, no systematic occurrences of negative prices have been observed, unlike in European electricity markets, and prices have been relatively stable. The analysis of market data does not support the claim that price reductions are caused by unexpectedly low demand levels. Two main factors explain this result. First, the average demand reductions of about 1,200 MW due to lockdown measures have been offset by the phasing out of Indian Point's Unit 2, a 1,299 MW nuclear power generating unit, during March. Second, large drops in fuel prices are the main culprits behind wholesale price reductions. In March and early April, average spot prices for natural gas and oil have been, respectively, 22% and 45% smaller with respect to their February levels.

Polluting emissions have remained stable due to the retirement of Indian Point's 2. The energy mix has not changed significantly, unlike in other regions. The only noticeable difference is the substitution of some dual-fuel production with gas-fired generation.

Potential longer-term consequences. The low price environment jeopardizes investment profitability in electricity markets. The 50% price reductions caused by fuel price drops may hinder new capacity additions in the medium to long run as investors update their expectations about future market conditions.

In addition, containment measures may delay the commissioning of current projects (renewable capacity additions, refurbishment of transmission lines, equipment maintenance, etc.) as all non-essential works are now on pause. Those delays could have detrimental consequences on small firms with tighter credit constraints in the renewable energy sector. Temporary load reductions from sheltering measures should nevertheless have virtually no effect in the long-run.

The most pressing issue for utilities in the U.S. is perhaps the suspension of $6.4 billion in pending rate hikes. It has been recently announced in many states, including New York, as a measure to protect the most vulnerable populations. Some utilities in New York have proactively asked to delay rate hikes through mid-September. Although it is a good news for residential consumers in the short-term, rate recovery of fixed-costs for utilities is essential to guarantee reasonable borrowing costs for large capital projects. The combination of delayed rate hikes and the financial struggle of energy consumers caused by containment measures may increase the cost of capital and ultimately affect energy bills in the long term.

Conclusion. Electricity consumption is a good indicator of economic activity. Containment measures have resulted in large demand reductions in the state of New York. The effects of lockdown measures on electricity markets are however quite limited. The unparalleled changes in daily load patterns have had virtually no short-term effects in terms of prices and system reliability so far. In the longer term, new installations may suffer from some delays and utilities may face the risk of increased borrowing costs due to suspended regulated rate hikes.

The COVID-19 crisis has brought two major challenges to electricity systems. First, forecasting models take several weeks to learn from new data and urgent adjustments are required to prevent inefficient system operations caused by large forecast errors. Second, and most importantly, system operators had to come up with a pandemic response plan to ensure the security of supply and safety of its employees. NYISO has perhaps implemented the starkest measures: 37 operators, managers and support staff volunteered for total sequestration from the outside world until further notice. "Just like planes can't fly without pilots and co-pilots, the electric system can't run without electricity operators", said NYISO's VP of Operations.

Footnotes

[1] Standard errors are calculated following an "honest inference" approach (Wager and Athey, 2017). More specifically, the test set is used to compute the covariance matrix of prediction errors across hours of the day. Assuming each day to be an i.i.d. realization of daily load, the sum of errors over the course of a week has the same distribution for all weeks.

[2] Estimated relative changes being ratio of random variables, the delta-method is used to calculate standard errors based on the previously estimated covariance matrix.

[3] http://www.ercot.com/content/wcm/lists/200201/ERCOT_COVID-19_Analysis_FINAL.pdf.

[4] https://www.nyiso.com/documents/20142/2923301/dayahd_schd_mnl.pdf/0024bc71-4dd9-fa80-a816-f9f3e26ea53a.

[5] https://www.nyiso.com/-/covid-19-and-the-electric-grid-load-shifts-as-new-yorkers-respond-to-crisis.

[6] https://www.rte-france.com/sites/default/files/impacts_de_la_crise_sanitaire_covid-19_sur_le_systeme_electrique.pdf.

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The Impact of COVID-19 on the Off-grid Renewable Energy Sector in Nigeria

BY ABDULRASHEED ISAH AND GYLYCH JELILOV

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See footnotes at end of text.

The coronavirus (COVID-19) pandemic brought a dreadful start to the decade. Although the COVID-19 outbreak originated in Wuhan, central China, it has since spread to almost every country, causing over 120, 000 deaths, and infecting around two million people globally as of April 16, 2020[1]. Moreover, the pandemic has triggered an unprecedented economic crisis as shown by the collapse of stock markets, slump in air travels, and major disruptions to global production and supply chain. The International Monetary Fund (IMF) projected that the global economy would contract sharply by -3% in 2020, with recovery expected in 2021[2]. Meanwhile, governments have responded with stimulus packages worth over $9 trillion in order to limit the economic impacts of the pandemic[3]

The pandemic has also disrupted the energy sector in fundamental ways. According to the International Energy Agency (IEA), oil demand plunged by over 30% as industries shut down and travels are restricted due to strict lockdown measures imposed across the world. As a result, oil prices dropped below $30, a fall of almost 50% between January and March 2020, thanks to both a slowing global economy and an initial lack of coordination among major oil-producing countries over production cuts.[4]

Furthermore, the pandemic may slow the global energy transition. Analysts forecast disruptions in the global supply chain of both solar and wind technologies due to the lockdowns in China and other major economies. The Bloomberg New Energy Finance downgraded its 2020 global solar demand forecast from 143 to 108 gigawatts and noted that wind energy faces "considerable downside risks".[5] However, others have claimed that low oil prices also present opportunities for governments to slash fossil fuel subsidies and strengthen carbon taxes in order to provide a level playing field for renewables to compete effectively. According to Fatih Birol, the Executive Secretary of the IEA, governments should "seize the opportunity" and put "clean energy at the heart of the stimulus plans to counter the coronavirus crisis".[6]

While a lot has been written on the effects of the COVID-19 outbreak on energy markets, little is known about how the pandemic is disrupting the decentralized clean energy sector in sub-Saharan Africa (SSA), where around 600 million people lack access to electricity. During this period of lockdowns, access to reliable and clean electricity is extremely important not only for households' wellbeing but also for powering healthcare centers at the forefront of responding to the pandemic.[7] In recent years, the use of off-grid solar solutions has become widespread across SSA and has been especially touted as a crucial vehicle for achieving reliable, affordable and clean energy access for all (SDG7). Between 2019 and 2022, the off-grid solar is estimated to provide access to clean energy services for over 740 million people, mainly in Africa.[8]

This article provides a preliminary analysis of the mechanisms through which the COVID-19 pandemic is impacting the off-grid solar sector in Nigeria and sub-Saharan Africa at large. An online survey was administered among members of the Renewable Energy Association of Nigeria (REAN), a body of solar home systems (SHS) companies and mini-grid developers across Nigeria, to elicit their responses on the channels through which their businesses have been disrupted by the pandemic and their assessments of the long-term effects for business sustainability and energy access. Also, interviews were conducted with five experts working in energy consultancy, development agency, and the Rural Electrification Agency in Nigeria.

The impact of COVID-19 pandemic on the Nigerian economy

Like other sub-Saharan African countries, the health

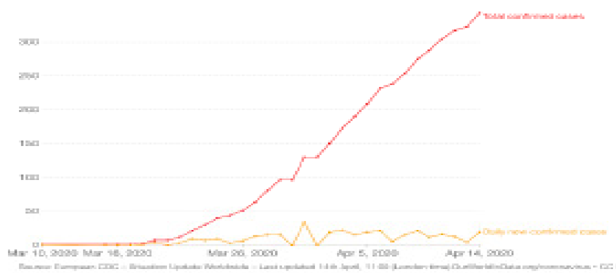


Figure 1: Total and daily confirmed cases of COVID-19 cases in Nigeria

impact of the pandemic is relatively low in Nigeria compared to Western countries. However, given weak health systems, crowded housing conditions, widespread poverty, as well as uncertainty over the future spread of the virus, the implications of the COVID-19 outbreak could be far-reaching in the country. As of April 15th, Nigeria has 343 confirmed cases of COVID-19 (Figure 1) but the number of new infections is rapidly rising. Some have argued that actual cases are much higher than the official figures due to low test capacity. The Nigerian government has imposed lockdown in Abuja and two other states

– Lagos and Ogun –, as well as restrictions in several other states, to curb the spread of the virus. Schools and airports have been shut across the country for several weeks.

Given that crude oil accounts for over 80% of public revenues and export earnings, the Nigerian economy has been hit hard by the pandemic. Crashing oil prices bring an enormous fiscal strain on the government, forcing it to cut projected expenditures in the 2020 budget. Between January and April 2020, Nigeria's foreign reserve has declined by $4 billion, the largest drop in several years, while the Nigerian Naira is fast losing its value even as the Central Bank of Nigeria (CBN) struggles to prevent a precipitous devaluation of the currency.[9] Combined, these foreshadow an imminent economic catastrophe in the country. The Nigerian government has responded by launching the COVID-19 Fiscal Stimulus in order to support the economy.[10] Yet, this would be largely financed through the borrowing of $6.9 billion from the World Bank and IMF due to limited fiscal space. Similarly, the Central Bank of Nigeria has announced a palliative package to encourage banks to extend credit to businesses to boost economic activity.

With an "inevitable" recession on the horizon in Nigeria, lower economic activity and heightened risks present significant challenges for the sustainability of the off-grid solar sector.

The status of renewable energy in Nigeria

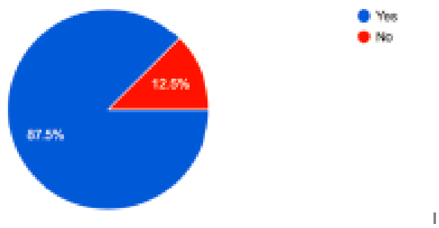
Electricity access remains a perennial challenge in Nigeria, where 77 million Nigerians lack access to electricity. Gas-fired power plants constitute 80% of electricity generation, while hydro-dams accounts for nearly all of the remaining 20%. Nigeria's non-hydro renewable energy resources have remained largely unexploited, with solar and wind energy accounting for less than 1% of electricity generation. Meanwhile, the country has high solar insolation levels, especially in northern Nigeria, vast landmass and strong wind speeds suitable for generating electricity using both solar panels and wind turbines. A recent article published in Climate Policy shows that standalone solar and hybrid mini-grids could provide modern energy access to over 88 million Nigerians by 2030[11], helping to avoid $14 billion annual spendings on diesel generator sets. However, achieving this requires increased investments into the off-grid solar sector, well-planned integration of distributed solutions into the energy infrastructure, and favorable policies.

Therefore, promoting access to clean energy is central to achieving and lifting millions of people out of poverty.

The impact of the pandemic on Nigeria's off-grid solar sector

While it may be early to assess the full effects of COVID-19 pandemic on the off-grid clean energy sector in Nigeria, findings from this research provide valuable preliminary evidence on the nature of the disruptions facing the sector and the implications for clean energy access in the country. We have organized the effects of the pandemic on the off-grid market under four themes: supply disruptions, demand shocks, shrinking investments, and slow energy access.

Have you experienced delays in procuring solar components during the pandemic period?

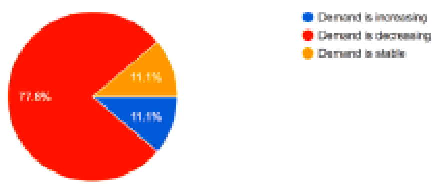


Supply disruptions

The immediate impact of the pandemic comes from the supply side of the decentralized sector. Due to lack of domestic capacity to produce clean energy technologies, the Nigerian off-grid businesses rely on the importation of solar components from China, Europe, and the U.S. Given that production has been affected in major economies over the past several weeks, the supply chain of clean technologies in Nigeria has been significantly disrupted.

The survey results indicate that about 88% of solar off-grid operators have experienced delays while trying to import solar components (such as panels, batteries, etc.) since the outbreak of the pandemic four months ago. This is likely to result in a shortage of solar products that would worsen unless countries adopt a coordinated response to ensure global trade continues smoothly. The majority of the respondents also expect more delays over the next 3 – 6 months as global trade is teetering from uncertainties amidst stranded shipments in China and other countries.

How is the demand for your off-grid services changing as more people stay at home?



Another major challenge to the supply chain comes from a shortage of workforce during the pandemic. The off-grid sector is labor intensive involving collaboration among networks of solar installers, technicians, sales agents, and distributors. Due to safety reasons and travel restrictions, most off-grid businesses in many states have halted operations because of limited manpower across the industry.

Demand shocks

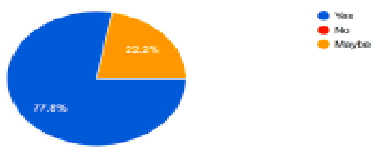
The impact of the pandemic on the demand side of the Nigerian off-grid energy market is mixed but generally indicates a downward trajectory. Around 78% of respondents reported decreasing demand from customers in the last several weeks, with adverse implications for business continuity and resilience of solar companies.

Falling demand is traced to specific factors facing customers. On the commercial side, micro, small and medium enterprises (MSMEs) that use roof-top solar PV are closed, thus, their energy use is minimal. On the household side, declining demand is attributed to income slowdown affecting people due to restrictions on economic activity. Given that most clients are in the lower- or middle-income class, they face a financial trade-off between buying essential goods (such as food) and meeting other needs (such as solar power); obviously, customers are more likely to prioritize the former. As one respondent put it, "in the context of [poverty] where people are struggling to survive, energy is not going to be a top priority". Moreover, travel restrictions make it harder for PAYGO[12] customers to reach sales agents to buy subscription cards for unlocking their solar solutions.

Shrinking investments

Nigeria has one of the world's largest off-grid markets with the potential to generate $8 billion in

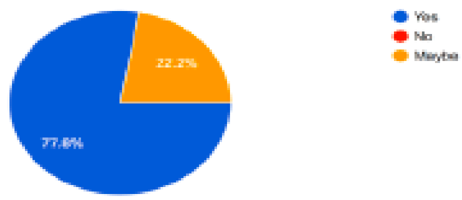
Do you anticipate that your business will experience financial difficulties in the next 3 months and above?



annual revenues[13]. However, investment into Nigeria's off-grid clean energy sector has been limited due to poor regulatory and policy frameworks, and lack of diversified financing instruments[14]. The COVID-19 pandemic is likely to shrink the already limited private investments in the off-grid sector by delaying ongoing projects and deterring new capital investments.

It was found that the pandemic threatens the financial sustainability of off-grid businesses. About 78% of the respondent reported that they anticipate experiencing financial difficulties over the next 3 months or so. Specifically, three factors compound financial risks in the sector. First, supply chain disruptions will limit sales growth over the next several months. Second, falling demand due to financial troubles facing customers is likely to cause liquidity shortfall in the off-grid market. Third, strict travel measures make it difficult to run businesses smoothly and complete ongoing projects. For instance, a respondent, who heads an energy consultancy firm in Lagos, reported that a visit to a mini-grid project site in Southwest Nigeria has been indefinitely postponed due to travel restrictions, thereby putting the project on hold. These factors have the potential to grind the sector to a halt.

Do you think that the pandemic would slow progress towards SDG7 in Nigeria?



Moreover, the pandemic has led to cancellations of planned conferences and indabas which traditionally connect off-grid enterprises with potential investors. About 67% of respondents know of a business event that has been canceled due to the pandemic. This is expected to reduce new investments and financial deal-making opportunities in the sector. Although online technologies are increasingly used to facilitate communications among different stakeholders in the industry, the pandemic would significantly reduce new physical investments due to the need for site inspections, solar installations, maintenance, among others.

Slow energy access

Energy access is central to human development and lies at the heart of achieving other SDGs such as zero poverty (SDG1), health and wellbeing (SDG3), and women empowerment (SDG5)[15]. Yet, energy access is not immune to the impacts of the pandemic. While it is premature to make a definitive claim, it is generally believed that the pandemic would slow progress towards achieving the SDG7 in Nigeria, with devastating consequences for millions of people without electricity. However, this depends on the length of the lockdown in Nigeria as well as the extent to which global trade in clean technologies is impacted by the pandemic. Besides, some expect that the pandemic would only have temporary effects on the off-grid businesses without having long-term crippling impacts due to the sheer size of the Nigerian off-grid sector.

Furthermore, assessing the effects of the pandemic on energy access would require observing how it affects the operations of the Rural Electrification Agency (REA), Nigeria's government department responsible for expanding access to electricity in remote communities, mainly using off-grid solar, as well projects run by development agencies such as the Solar Nigeria Program and Power Africa. A staff of the REA said that the agency is only operating "skeletal services" involving limited managerial activities. Project monitoring and evaluation have been canceled which would obviously delay the disbursement of grants to mini-grid developers. Although the REA released a statement that it would facilitate the disbursement of grants to mini-grid developers during the pandemic period, there has yet to be any payment and it remains unclear whether the agency can operate efficiently remotely. More broadly, the pandemic would be detrimental to plugging the huge electricity access gap in Nigeria.

In addition to its enormous health and economic impacts, the COVID-19 pandemic is taking its toll on the off-grid clean energy sector in Nigeria and Africa at large. This article showed that the pandemic has led to supply chain disruptions, declining demand, falling investments and reduced energy access in the Nigerian off-grid renewable energy sector. Given the bleak economic outlook of the country, the off-grid solar industry is likely to trail behind even if the economy reopens in the nearest future. Yet, the off-grid industry, financial institutions and governments across sub-Saharan Africa can help keep the lights on for vulnerable people through a coordinated response.

Off-grid energy companies should prioritize the continued provision of power to communities as long as it is feasible, even in the event of non-payment by some customers. This will ensure that energy access is available to support economic activity and limit the economic damage on vulnerable customers at this difficult time. Customers should be given the option to pay at a later date or even better, the government should subsidize the bills of poor customers. The off-grid industry should also leverage technological solutions (e.g., AI and mobile money) to sustain efficient operations without putting their workforce at risk of the virus.

Financial institutions can support the off-grid sector through the provision of long-term finance. As Nigerian banks often do not lend to off-grid businesses, this is the right time for them to extend vital loans to help the sector to thrive financially. Banks could also extend maturities of existing loans without additional interest payments. For instance, the latest decision of All On[16], an off-grid clean energy impact investment company, to suspend interest payments on all its loans to solar companies in Nigeria throughout Q2 2020 is highly commendable and should be followed by other investors. Similarly, multilateral agencies like the World Bank need to provide more grants specifically targeting decentralized renewable energy companies, making them part and parcel of responding to the pandemic and building resilience in poor African countries.

The government's first line of support is to facilitate the clearance of clean energy products at the ports and to allow their easy transportation nationwide to minimize supply chain disruptions. This is crucial because solar companies often complain about long queues and customs delays as major logistical challenges. The government could also support solar companies by lifting import taxes on clean energy technologies, extending concessional loans and emergency grants, and ensuring favorable policies and regulatory frameworks. It is encouraging that the Nigerian government is collaborating with the off-grid energy industry to deploy solar to power in COVID-19 response facilities, potential isolation centers, and other healthcare centers. Given that less than 28% of health facilities in sub-Saharan Africa have reliable electricity, this is an innovative effort that would not only help in ensuring constant power in health centres but would also create new demand in the off-grid industry, helping companies to remain afloat.

More broadly, the government should recognise energy access as an essential service and facilitate strategic operations of off-grid solar companies especially in rural areas. Lastly, the government should encourage domestic production of clean energy technologies in order to mitigate against future supply chain disruptions and create green jobs in the decentralised renewable energy sector.

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Impact of the Coronavirus on the Greek Energy Market

BY KOSTAS ANDRIOSOPOULOS, KYRIAKI KOSMIDOU AND FILIPPOS IOANNIDIS

Introdction

At this early stage of the crisis, it is fairly difficult to address the disastrous effect that COVID-19 is anticipated to have on the energy markets all over the world. However, it is crystal clear that energy markers have been negatively affected by a huge decline of both supply and demand. This decline is apparent in the volatile oil markets, in the significant slowdown of industrial activity, in the simultaneous decrease of electricity demand, in the delays of ongoing developing projects of Renewable Energy Sources (RES) and in the deterioration of global natural gas trading. This article attempts to provide an early analysis of the ongoing crisis, by reviewing the current state of the Greek energy market and carefully drawing direct links in terms of short and long-term consequences.

Global Uncertainty

As the coronavirus causes economies around the world to come to a standstill, two issues are most difficult to answer. First of all, what would be a reasonable timeframe for reducing coronavirus expansion that would allow economies to return back to normality and secondly, what would be the overall consequences of this extremely abnormal situation for national economies. Considering the second part, governments and central banks globally provide massive liquidity packages aiming to maintain vital sectors from instantly crashing, since otherwise many companies will default on their debt and a huge domino effect will commence. An aftermath of this support is the duration of such policies that will eventually lead to a fragile highly inflated economic environment.

In that context, the energy sector is expected to be significantly affected in various ways. To begin with, the global oil market is currently facing a toxic combination of low demand and a price war declared by Saudi Arabia and Russia which affects all major producers globally. Another sector that faces severe problems is the RES market, since photovoltaic factories in China have just started to operate in full capacity again after two months of reduced output. In the United States (US), the national photovoltaics association requested to be included in the 2 trillion rescue package that was approved by the authorities. In Europe, many companies have asked for extensions to their project deadlines since the arrival of necessary equipment delays from China.

Moreover, a similar unknown environment holds for the wind market, since wind plants stopped operating in various regions, while in large markets such as Italy, Spain and France restrictions in workers mobility postpones the development of new projects (Frangoul, 2020). Considering the effect on natural gas, normality is anticipated to return once the Chinese economy is back on track, although a significant decline in total demand for power generation already takes place in Europe and in the US. At the same time, Liquified Natural Gas (LNG) and pipeline prices are expected to drop at historical levels.

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Main Implications in Greece

As the majority of countries globally, since March 23, Greece announced a lockdown, restricting movement for all citizens. The strict measures that followed are anticipated to significantly hamper economic growth lead to a huge recession. Aiming to support the Eurozone economy throughout the pandemic, and in contrast to previous rounds of quantitative easing, the European Central Bank (ECB) has decided to include Greek bonds in its 750 billion-euro asset-purchase scheme. ECB has also relaxed its rules, so that banks will be able to post Greek sovereign debt as collateral when they take up liquidity from the central banks. These decisions aim to provide additional stability for the country's financial markets (Guigliano, 2020).

Considering the case of the Greek energy market, national authorities announced a plan that could act as a guarantee mechanism for energy suppliers, aiming to provide a cushion towards the imminent liquidity shocks. The majority of energy companies are offering discounts on energy bills but, at the same time, face the possibility of increased arrears. Interestingly, CO_2 and LNG's low prices provide incentives for the thermal plants of the Public Power Corporation (PPC) to be more competitive and operate in reduced cost. On the other hand, the drop of CO_2 price triggers some positive and negative effects:

- A positive effect comes for electricity suppliers who buy electricity quantities in lower price comparing to previous market price levels, thus increasing their profit at least until competition bring prices to equilibrium. Average wholesale monthly system marginal price has decreased by more than 20€/MWh comparing to 2019 levels, without considering the effect of CO_2 emission drop. According to the Hellenic Association of Photovoltaic Energy Producers (2020) this will result to a decreased costs of at least €700 mil for all electricity suppliers sector, for 2020.

- A negative effect comes to RES producers who are receiving their revenues from the Specific RES Account managed by DAPEEP. Important inflows to RES account are (i) the wholesale market revenues and (ii) the RES levy. Both are affected during this period and based on the Hellenic Association of Photovoltaic Energy Producers (2020) estimations, this deficit could reach 423 mill euro at the end of 2020.

3.1 Oil and Refining

Below we provide, the most important negative consequences that the sector currently faces:

A significant drop in fuel sales in the domestic market, mainly due to a reduction in the demand for aircraft fuels (up to 100%), for gasoline (up to 70%)and for diesel (up to 50%).

Reduced exports in almost all countries

- Companies operate with the least possible staff to ensure the uninterrupted operation of the facilities and the supply of the market. This also leads to the limitation of parallel daily activities, such as the execution of projects and the development of new investment plans.
  Difficulty in dealing with issues of operation and maintenance that require the presence of specialized foreign technicians due to travel restrictions. However, this limitation could be withdrawed in case of emergency.
- Delays in the delivery schedule of spare parts and equipment.
- Delays in the licensing of mature investments that directly affects future cash flows.
- On the other hand, a couple of positive consequences are apparent as well:
- Households obtain huge amounts of oil for heating purposes, which due to the extremely low prices is attractive and many consumers aim to take advantage of it for next winter season. Since the beginning of the year, heating oil prices has shown a significant reduction from 1.07 euros/liter to 0.815 euros/liter.
- Companies can supply raw material for the operation of refineries at lower prices.
- ncrease of raw materials and products so that the smooth return to pre-crisis conditions is not gradually affected.

In order not to disrupt the supply of this vital fuel to the market, companies that operate in the oil sector propose the simplification of the licensing process for the operation of ready-made investment projects by issuing a temporary electronical license, only for the period when restrictive measures applies.

3.2 Electricity

The consequences of the COVID-19 outbreak towards the companies and employees of the electricity market are numerous as well. First of all, part of the commercial, business and supply chain activities have been suspended. In parallel, thousands of job positions have been affected, and this negatively impacts economic output and prosperity. Aiming to guarantee security supply, the majority of electricity companies took instant measures throughout the generation chain and at the most critical infrastructures. Indicatively, the companies characterized specific areas (such as, unit control rooms and mines) as critical with controlled entry and mandatory use of protective equipment for the employees. Next, a classification of staff into categories (critical, supportive, alert) followed, and units maintained only the emergency staff on a rotating basis.

No particular problems have been reported so far in the supply chain. However, the constant operation of companies that supply the facilities with materials for continuous consumption (chemicals, lubricants, etc.) or other critical materials (especially when they are necessary for the implementation of station maintenance) is vital for the smooth functioning of thermal plants. This issue becomes more serious in the case of supplies coming from other countries or the when there is a need to send spare parts abroad for inspection and reconstruction. Another possible problem might rise from the restriction of travels that may affect the availability of units on non-interconnected islands. During the summer season, where normally a demand peak is observed, the availability of units may be reduced to a greater extent. Hence, given the current circumstances of high uncertainty, it is necessary to carefully forecast the load demand of the upcoming months. Besides, the strict measures created serious problems in a number of investment projects that heavily impacts their schedules and costs.

Another major issue is the fact that the implementation of the Target Model, that was initially designed to begin in June 2020, is anticipated to take place by a two- or three-months delay. In terms of commercial operations, the majority of electricity companies introduced discounts for their clients and allowed more than 85% their staff to work from home. Aiming to better serve the public, the service provided by call centers were extended to 14 hours per day and at the same time employees at the specific department increased by 50%. The main issue that will arise in the upcoming period for all electricity suppliers is the lack of liquidity, since, by the begging of March 2020, a reduction greater to 20% have been recorded in terms of collectability.

Regarding RES, the delay in development and licensing procedures for new investments is the most important issue that affects sector’s growth. Under development RES projects who secured tariff through a

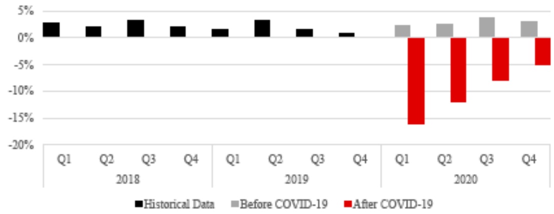

Figure 1: Quarter Change in GDP Growth Rate in Greece (%)
Source: Hellenic Statistical Authority and Authors' Estimations

tender face strict connection deadlines, with the risk of bank guarantees forfeiture. A recent legislative act have extended deadlines and licenses duration

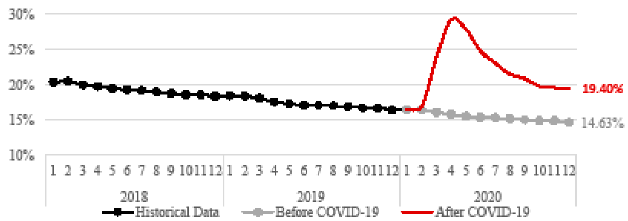

Figure 2: Unemployment Rate in Greece (%)
Source: Hellenic Statistical Authority and Authors' Estimations

covering most of the cases, but still, this act needs to be extended to all cases. It should be noted that no force majeure event has been predicted on RES tender rules to protect successful tender bidders. National authorities need to guarantee flexibility for the development and completion of renewable projects.

Besides, Greece should support EU fund to

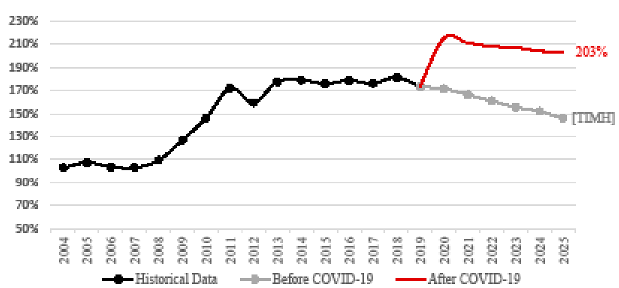

Figure 3: Government Debt as Share of GDP in Greece (%)
Source: Eurostat and Authors' Estimations

encourage additional national renewable energy auctions and freeze degressive support schemes. Aiming to support financing and liquidity of RES market, the government should create a compensation scheme for RES developers and project owners for additional project costs due to the crisis. The RES levy should become a part of the competitive charges instead of being a regulated charge, at least as a temporary measure activated during this crisis. Furthermore, Greece should support to the European Commission SURE program as a job retention scheme.

In overall, the adverse effect has already been

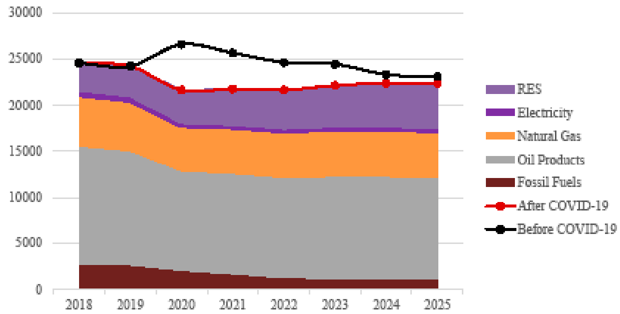

Figure 4: Evolution of Gross Energy Consumption in Greece (ktoe)
Source: National Plan for Climate & Energy and Authors' Estimations

apparent mainly through the significant reduction in electricity demand, which is more than 15% on average, compared to the same period a year ago. At the same time, the reduction in companies' revenues

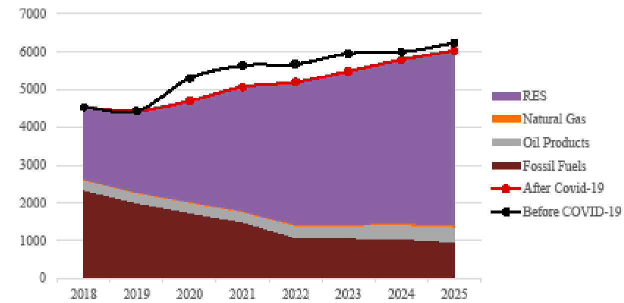

Figure 5: Evolution of Primary Energy Production in Greece in Greece (ktoe)
Source: National Plan for Climate & Energy and Authors' Estimations

is estimated to be more that 20%. Based on the above, we argue that electricity suppliers should be strengthened by government interventions, especially with measures that will improve liquidity, such as a generous reduction in corporate tax.

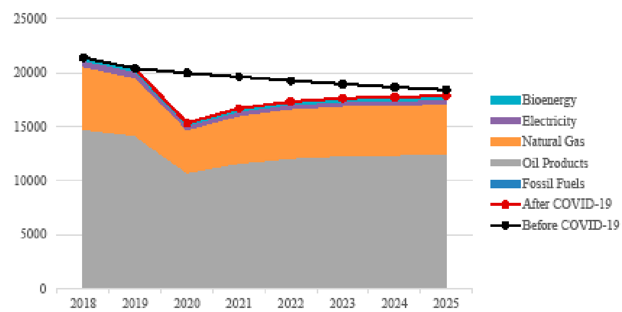

Figure 6: Evolution of Net Energy Imports in Greece in Greece (ktoe)
Source: National Plan for Climate & Energy and Authors' Estimations

Economic Outlook

Based on national authorities' estimations, the quarterly GDP growth rate prior to the outbreak of COVID-19 was projected to be 2.8% on average for 2020. However, based on IMF's recent estimations

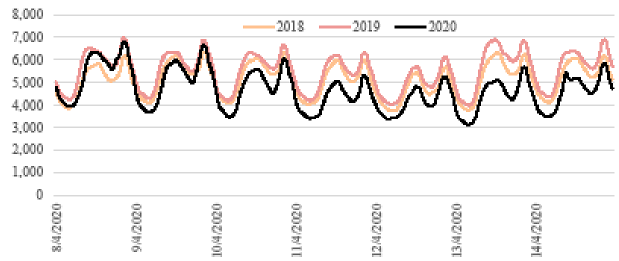

Figure 7: Historical and Current Data on Electricity Load in Greece (MWh)

(IMF 2020), the projection following COVID-19 will lead to an average annual decrease of GDP by 10%. The projection for unemployment rate is expected to

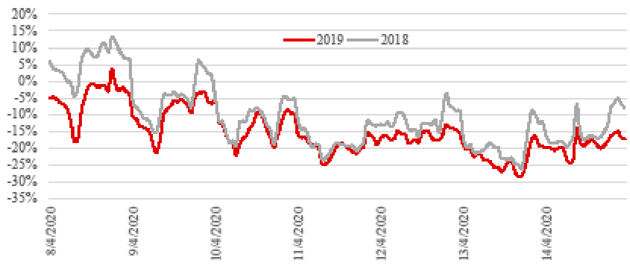

Figure 8: Change in Hourly Electricity Load in Greece (%)

Source: HEnEx and Authors' Estimations

face a short-term inverted U-shaped curve. Based on IMF's estimations 235.000 jobs will be lost during the upcoming months, leading to a yearly unemployment

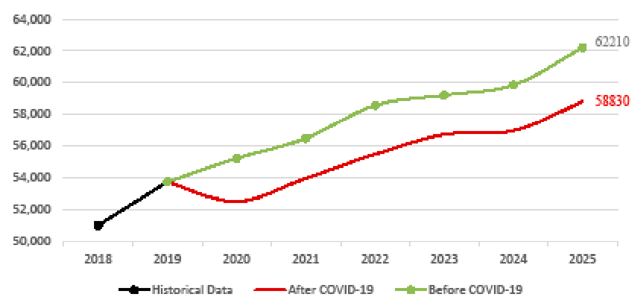

Figure 9: Evolution of Total Demand for Electricity in Greece (GWh)
Source: National Plan for Climate & Energy and Authors' Estimations

rate of 22.3% for 2020. The projection for 2021 is that unemployment will stand at 19%.

The projection for the government debt as share of GDP before the outbreak of COVID-19 was based on

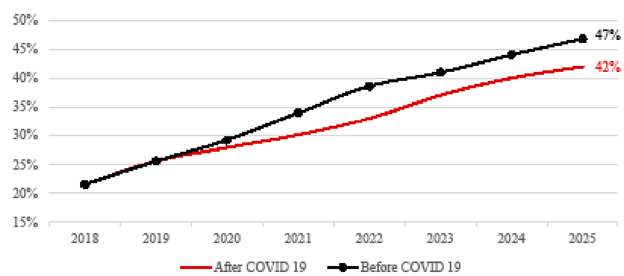

Figure 10: RES share in Gross Electricity Consumption in Greece (%)

Source: National Plan for Climate & Energy and Authors' Estimations

estimations provided by the International Monetary Fund (IMF, 2019) and the recent Greek budget (2020). However, we anticipate a significant increase in the percentage of debt to GPD by more than 30% compared to 2019 levels.

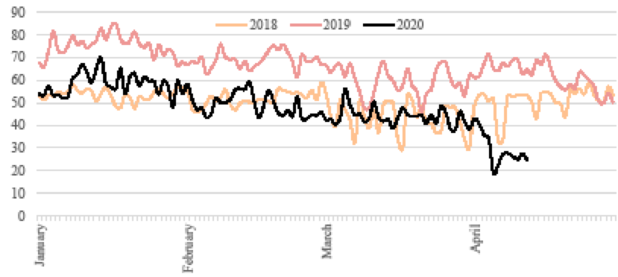

Figure 11: Daily Electricity Price in Greece (€/MWh)

Source: HEnEx and Authors' Estimations

Energy Market Outlook

Gross energy consumption in 2020 is anticipated to decrease by almost 11% in 2020 but compared to prior

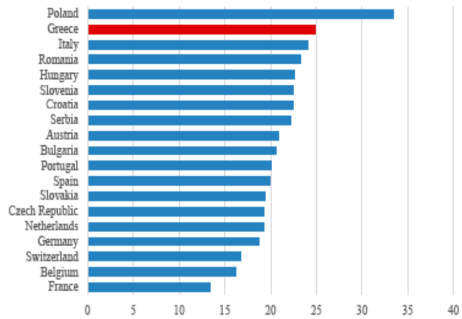

Figure 12: Daily Average Electricity Price for Selected Countries (€/MWh), [5/4/2020 - 12/4/2020]

Source: EPEX SPOT, IBEX, OPCOM, OMNIE, CROPEX, GME, ENTSO-E, HENEX, SEEPEX, SOUTHPOOL and Authors' Estimations

projections the reduction is up to 18.5%.

However, in the long run, this gap between the two projections will gradually decrease, reaching at almost identical level by 2025. Throughout this period, it is apparent that consumption from RES will increase while energy consumption from fossil fuels will

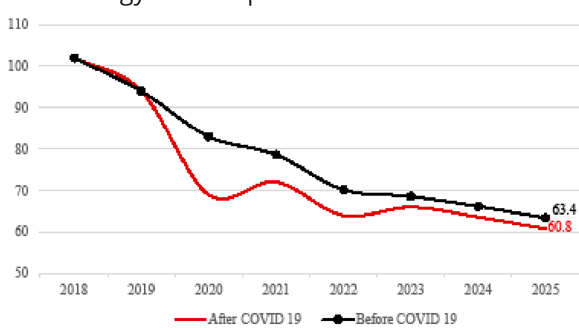

Figure 13: Evolution of Total CO2 Emissions in Greece (MtCO2)

Source: National Plan for Climate & Energy and Authors' Estimations decrease.

Despite the COVID-19 crisis, primary energy production in Greece is anticipated to follow an upward trend that is however hampered by 11.3% compared to prior projections. By the end of 2020, RES are anticipated to represent 75% of total energy produced in Greece. Regarding the evolution of net energy imports, we anticipate a huge drop for 2020 and a gradual increase during the upcoming years.

Figure 7 depicts the total electricity load during the second week of April compared to the same variable during 2019 and 2018. The relationship between economic growth and electricity consumption is well documented by prior research (Narayana and Prasad, 2008). In that context, Figure 8 illustrates the change in hourly electricity load for Greece. The maxim reduction was recorded during 13th of April 2020 by 28.45%, and the average reduction for the week under examination is 10.54% and 15.24% compared to 2018 and 2019 levels respectively.

Total demand for electricity in 2020 is expected to lower by 2.2% compared to 2019 levels, and then it is expected to follow an upward trend. Besides, due to significant delays in licensing procedure of RES projects, an overall decrease of 5% is projected to take place in RES share in gross electricity consumption by 2025.

Daily electricity prices in Greece are substantially lower compared to 2019 levels. a historical minimum of 18.7€/MWh was recorded during the first week of April 2020. This is interpreted as a 70% decrease compared to the price of 64€/MWh that was recorded for the same day in 2019.

Despite this sharp drop in electricity prices, a comparison among various EU countries reveals that during the second week of April 2020, Greece faced the second highest electricity price, with a daily average price of 24.8€/MWh.

Finally, on the positive side of the current crisis, the total amount of CO_2 emissions in Greece is expected to sharply decrease in 2020, however, as the economy will progressively return to prior levels, a slight increase will follow in 2021. In overall, a downward trend will follow until 2025, reaching the level of 50.8 $MtCO_2$ which is slightly below the value of prior projections.

Conclusions

This paper focused on national perspectives after the outbreak of the COVID-19 in the Greek energy market. During this unprecedented crisis, all sectors of the economy, both at local and global framework, will need rapid measures and direct actions towards recovery. The energy sector will certainly need significant support aiming to reach again the prior levels of demand and supply. In that context, the progress of the Greek energy sector depends to the greatest extent on new investments. The evolution of investments depends on the economic climate, which will significantly be affected by total consumption. Inevitably, total consumption will also be affected, hence the necessity for state mechanisms assistance in the field of liquidity, licensing, legislation, approvals and bureaucracy is more than vital.

Under such times of emergency, government innervations must display a quite different behavior from the way we have been accustomed to so far. Sooner or later, the economic climate will improve, and consumption will return back to normal. In the meantime, market participants must be ready to immediately restart their productive and investment activities. Strategic projects and large investments face time consuming bureaucratic issues that still hold these projects away from being implemented. Namely, East-Med, Kavala underground gas depot, the exploration for the exploitation of hydrocarbons in Western and Southern Greece, plethora of RES projects, the installation and operation of offshore wind turbines and cable interconnections, are only a few examples of potential investments in the Greek energy sector. In that context, the most efficient way to support those investments and at the same time assist economic growth is to simplify and speed up the legal and bureaucratic procedures. Otherwise, the significant positive momentum that the Greek economy had gained after a decade of severe crisis, will be lost again, with devastating consequences for the society.

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Impact of COVID 19 Virus Cases and Sources of Oil Price Shock on Indian Stock Returns. Structural VAR Approach

BY BHAGAVATULA ARUNA AND ACHARYA H. RAJESH

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See footnotex at end of text.

Introduction

March 16th 2020 "The spread of the novel coronavirus has now turned into a disruptive financial contagion and demands quick action from India's policymakers and regulatory bodies." (Economic Times, Market).

April 14th 2020 "The impact of the coronavirus pandemic and the lockdown it triggered is clearly visible in financial markets" (Economic Times, Market). The above headlines from the popular financial press provide evidence that the outbreak of COVID 19 had a drastic impact on the Indian stock market. Although China (Wuhan) became epicentre of COVID 19, soon the disease affected around 2,00,000 and at least 100 countries. On 11th February 2020 World Health Organization (WHO) declared COVID 19 as pandemic. This triggered anxiety and stress in financial markets. Many European economies are severely affected. Although the number of cases has declined in China and lockdown has been relaxed in most of the provinces in China, there are many countries, which witnessed the disease by early March are yet to relax the lockdown. Similarly, Indian Prime minster, Mr Narendra Modi declared a national lock down effective from March 25th 2020 for three weeks. Following which Reserve Bank of India took monetary steps to mitigate corona virus crisis. It cut the repo rate and the reverse repo rate by 4.4% and 3.75%, respectively. Also, the decision of Saudi Arabia to increase the supply of oil lead to an oil crash. This has led to debate whether the impact of outbreak of corona virus has resulted in international oil price dip. Our study revisits the relationship between the sources of oil price shock and stock returns during corona virus spread. Moreover, India being oil importer, whether the drop in oil price has a positive influence on stock market or not? Will low oil prices benefit Indian economy?

By far, the existing literature is mainly concerned with a study of the impact of real oil price on stock returns, but there is no consensus in the literature. While Kling (1985) finds that real oil price increase results in stock market decline, Chen et al. (1986), and Jones and Kaul (1996) find no association between oil price and stock returns. Apergis and Miller's (2009) study found that oil price volatility had negative influence on stock returns. Other popular studies which concluded negative relation between real oil price and stock returns are Basher and Sadorsky (2006), Chen (2009), Jones and Kaul (1996). Kumar and Gupta (2014) found that the aggregate stock returns were more sensitive to negative change in oil prices than to positive change in oil prices. However, several studies have found positive relation between real oil price and stock returns (see for example, Zhu, Li & Li, 2014; Zhu, Li & Yu, 2011; Narayan & Narayan, 2010). Sadorsky (2008) concluded that oil price volatility positively affected the United States stock return. Managi and Okimoto (2013) also found positive relationship between oil prices and stock returns.

In our study, we assess the impact of COVID 19 and different oil price shocks on Indian stock by using the methodology propogated by Kilian (2009). Extending the previous studies that considered oil price shock proxy for oil specific demand, we use oil inventories in our analysis for measuring speculative demand. While using oil inventories, we treat them as tool to identify the forward-looking component for oil price shocks. The idea of using speculative demand is to separate speculative component from demand and supply shocks of oil. According to our knowledge, this is the first study to assess how COVID 19 cases has changed dynamics between different global oil market shocks and Indian stock returns.

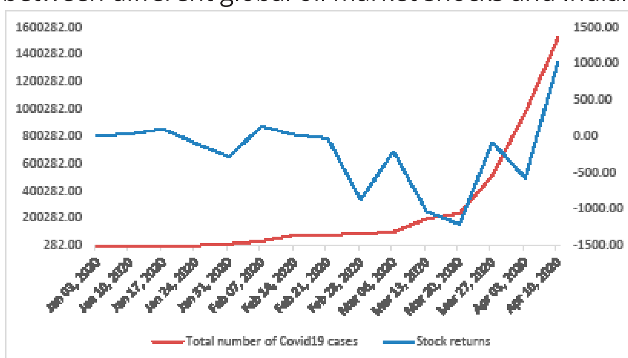

Fig 1. COVID19 cases and stock returns

The paper proceeds as follows: section 2 describe data. Section 3 deals with methodology, section 4 describes empirical results while conclusion is provided in section 5.

Data description

WHO data shows that worldwide COVID 19 cases (left hand scale) has been rapidly increasing from February 28th. Therefore, we are assuming that increase in COVID 19 cases may have drastic effect on financial markets. Figure 1 also shows that stock returns increases exponentially and seems to be positively correlated with COVID 19 cases. We extract weekly COVID 19 total confirmed cases data from WHO situation reports.

We estimate a two variable SVAR-X using weekly data from January 3rd 2020 to April 10th 2020. As stock market is considered important component of economic and financial set up the present study considers the closing price of stock prices of companies listed in Nifty 50. The stock returns are obtained from the first difference of natural log of stock prices. We include the price of crude oil based on weekly Europe Brent spot price FOB (Dollar per Barrel) obtained from U.S. energy information adminstration (EIA). Following Kilian (2009a), the real price of oil is expressed in log-levels. We also obtain the weekly data for the global oil exports measure in millions of barrels of oil from U.S. Energy Information Adminstration. Following Killian and Murphy (2012), we extract data for petroleum inventories provided by the EIA.[1] We use OECD countries as proxy for global petroleum inventories. We use E-GARCH in order to measure the shock in inventories, referred to as 'speculative demand'.

Methodlogy

In order to capture oil price shock, previous studies have used the traditional method of modelling shock by taking standard deviation of the series. This concept was proposed by Ferderer (1996) who modelled oil price shock by taking the standard deviation of the oil price. Unlike other studies, we use Exponential-GARCH (E-GARCH) in order to capture the shock. Basically, the methodology used under GARCH and its family (T-GARCH, E-GARCH etc.) is to record shock from the residuals of the error term of the series. E-GARCH is stated in log form for variables, which means the model is free from parameter restrictions, and E-GARCH is specified as follows:

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{r} \beta_j h_{t-j} + \sum_{k=1}^{m} \theta_k \ln(\sigma_{t-k}^2) \qquad (1)$$

where h_t is specified as the conditional volatility of the oil price, and α_0 is the unconditional variance with constant mean. Hence, using E-GARCH methodology, we calculate different types of shocks pertaining to COVID19, oil export shock, and oil specific demand. Shock arising from total number of cases is referred as shocks in oil exports are denoted as global export shocks; and finally, any shock arising in inventories is represented as speculative demand shock in order to measure the forward-looking behaviour.

Econometric Analysis

Structural Vector Auto-Regressive (SVAR-X) Model

While following Kilian (2009), we represent the transmission of oil price shocks using our reduced-form structural VAR model for 24 months lags.

$$A_0 Y_{it} = L_{io} + \sum_i^k B_1 Y_{it-1} + B_2 Y_{it-2} + \dots B_n Y_{it-n} + \phi X_t + \varepsilon_{it} \qquad (2)$$

In the equation, matrix specifying contemporaneous relationship among the variables is represented by A. Y_{it} is a (Kx1) vector of two endogenous variables such that $Y_{it} = Y_{1t}, Y_{2t}, \dots Y_{nt}$ (stock returns and inflation). L_{io} is a (Kx1) vector of constants constituting firm-specific intercept terms. The matrix of coefficients with lagged endogenous variables (for every i=1....P) $\emptyset$ is represented by B_i. B_i is also polynomial in the lag operator, and restrictions are typically imposed on the coefficient matrices. In our model we impose restrictions on our endogenous variables such as stock returns. Vector of coefficients is represented by X_t. K is the number ε_{it} representing the vector of uncorrelated error terms. ε_{it} is categorised into two sections of which the first section consists of shocks related to sources of oil price shocks and COVID 19. While the second section captures the variable of interest- Indian stock returns. Hence, following Kilian and Murphy (2012)`s methodology, error term (ε_t) in the first section consists of shocks in oil exports (oil export shock). Any shock to the oil inventories arising from speculative behaviour regarding oil demand and supply flow (speculative demand shock) is employed to record innovations in oil inventories. In order to capture all structural shocks, we also consider residual shock in the first section of error term. In the second section, innovations to stock returns are captured.

Equation (3) can also be written as:

$$Y_{it} = Z_i + A(P)Y_{it} + H(P)X_t + \nu_{it} \qquad (3)$$

Where specifications for Y_{it} and X_t are given as:

Y_{it} = *(Stockreturns)* (3.1)

X_t = Source of oil price shocks (3.2

Endogenous variables in the study are specified in equation (3.1). X_t in equation (18.2) represents vector of the innovations (shock). Equation (3.1) describes the vector of Firms' endogenous variables used in the study; equation (3.2) describes the vector of the exogenous variable that reflects shocks. Z_i stands for a vector of constants representing firm intercept terms. A(P) and H(P) specify the matrices of polynomial lags, which capture the relationship between the endogenous variables and their lags

$v_t = I^{-1}\mu_{\varepsilon_{it}}$ is a vector of the error term. Following Amisano and Giannini (1997) ` method we impose 7 restrictions[2] on the A.

Based on economic theory, we impose restrictions, and discuss how each variable is placed for identification purpose. Here we are assuming that shock arising from outbreak of COVID-19 affects oil price, oil supply chain and economic performance of the country. We also assume that the real price of oil is explained by the current and future supply and demand conditions. Any disturbance in oil export will lead to increase in the price of oil. Any disruptions in oil export will lead to shock in inventories. That is why our model also assumes that any shock in oil export will lead to disturbance in inventories. Any speculation regarding oil demand or supply will impact the current volume of inventories, and successively, the current oil price. Finally, our model assumes that COVID-19 shock and all the sources of oil price shocks affect the stock returns. So, the focus of this study is to assess the impact of the COVID-19 shock together with sources of oil price shock on Indian stock returns

Estimated A_0 matrix				
	COVID19-Shock	Oil Price shock	Oil Export Shock	Speculative Demand Shock
Stock Returns	75.67*** (57.52)	215.97*** (0.26)	-279.58*** (52.36)	-63.10*** (55.23)
Oil Price	-2.52*** (0.235)	1	-2.49*** (0.22)	3.62*** (0.12)

Table 1 Estimated Matrix with impact of Covid19 and Sources of Oil Price Shock infection on Oil Price and Indian Stock Returns (SVAR- X)

Table 1 exhibits SVAR, *** indicates significance at 1% level, ** at 5% level and * at 10% level.

The restrictions imposed on two endogenous variables are reported in equation 4. All the dependent variables are placed in first row left hand side of the matrix (stock returns and oil price). whereas OPS, OES and SDS stand for Oil Price Shocks, oil export shock, and speculative demand shock respectively. Real oil price and stock returns are determined by these above-mentioned shocks. All NAs depict the variables to be estimated. For example, oil price can be determined by COVID19 shock, its own shock, oil export shock and speculative demand shock. Stock returns is determined by COVID19 shock, oil export shock and speculative demand shock.

$$\begin{array}{cc} & \begin{array}{cccc} COVID19Shock & OPS & OES & SDS \end{array} \\ \begin{array}{c} Stockreturns \\ Oilprice \end{array} & \begin{bmatrix} NA & NA & NA & NA \\ NA & 1 & NA & NA \end{bmatrix} \end{array} \quad (4)$$

Empirical Results

The estimation results of the structural VAR model are presented in Table 1. Results present responses of the real oil price and Indian stock returns to outbreak of COVID 19 pandemic shock and various sources of oil price shock, viz oil export shock and speculative demand shock. The first row of table 1 shows the response of stock returns to COVID 19 pandemic shock and oil price shock and its sources. The sign of the COVID-19 coefficient is positive and statistically significant. Which means that there is positive influence of shock obtained from COVID-19 on stock returns. This indicates that COVID-19 shock may not have immediate negative impact on stock returns. The sign of coefficient associated with the oil price shock is also positive and statistically significant, indicating shock in spot oil price has positive influence on stock returns. On the other hand, shock obtained from oil exports has negative influence on stock returns. It implies that any disturbance in oil exports indirectly affects stock returns. These results are similar to those of the study done by Kilian and Park (2009): the study concluded that U.S. stock returns reacted similarly to oil supply shock. Similarly, Likewise, a study done by Ghorbel and Younes (2009) concluded that a negative oil supply shock has negative impact on stock returns of some of the importing countries. Similarly, shock arising from inventory oil also has negative impact on stock returns. These coefficients are statistically significant. These findings are similar to the findings of Guntner (2011), which concluded that stock returns are negatively impacted by a speculative demand shock.

Conclusion

Rapid increase in COVID-19 infection world wide did have negative repercussions on financial and commodity markets and economy as well. The magnitude of disturbance in economy due to outbreak of disease dependence upon monetary and fiscal policy response to COVID-19 outbreak. The present study analysis whether the COVID-19 number of cases has generated any shock in stock market. Our analysis reveals that there is no significant negative impact on Indian stock market. Hence, we can conclude that by far outbreak of COVID-19 has positive influence on stock market. The reason could be that there is no immediate impact on country`s economy. Also, the impact is for short-run, however, the long-term impact could be contrary.

Footnotes

[1] EIA includes crude oil as well as unfinished oils, natural gas..

[2] Based on calculation: 2n2-n(n+1)/2 (where n is the number of variables

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Nigeria and the Corona Virus Pandemic

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Introduction

December 2019 birthed some pneumonia cases in Wuhan, China. According to some laboratory findings, the sickness was caused by a virus called Corona Virus (COVID-19). The disease is a new virus linked to some family of viruses known as Severe Acute Respiratory Syndrome (SARS) and was described as a deadly disease that causes serious respiratory conditions as well as influenza. The virus spreads primarily when an infected person coughs or sneezes and by touching of contaminated surfaces. Some medical experts also explained that the virus is airborne and can be transferred from one person to another. The virus comes with symptoms of fever, cough and shortness of breath. In more severe cases, infection can cause pneumonia or breathing difficulties. The outbreak of this pandemic has spread across 196 countries with 1,607,595 confirmed cases, 95,785 deaths and 357,164 recovered persons as at Friday, 10 April 2020.

The Pandemic Behavior in Nigeria

In Nigeria, prior to the first confirmed case of COVID-19 of an Italian citizen on 27 February 2020, the government had on 31 January 2020 set up a "Corona Virus Preparedness Group" to fight the pandemic, as Nigeria was listed amongst thirteen high-risk African Countries by WHO. Due to the increase in number of people infected with the virus, on 9 March 2020, President Muhammadu Buhari established a Presidential Task Force to curb the spread of the virus and Federal Executive Council (FEC) meetings were indefinitely suspended. The Nigerian Senate responded by adjourning its' plenary session to 7 April, whilst the Nigerian House of Representatives adjourned indefinitely.

COVID-19 has nosedived religious activities as churches and mosques obey the ban on religious and social gatherings of more than 20 to 50 persons. Based on the foregoing, some churches resorted to "house-fellowship" and "electronic fellowships" to observe their Sunday worship.

The education sector was not left out as about 30 states announced immediate closure of schools and tertiary institutions ordered to shut down instantly. Consequently, the National Examination Council announced indefinite postponement of the March 2020 common entrance examination into 104 unity schools. The Joint Admissions and Matriculation Board suspended all activities for two weeks, whilst, the National Youth Service Corps' orientation which was scheduled from 10 to 30 March was ad infinitum suspended after 8 days of commencement. Also, the Professional examination bodies in Nigeria (Chartered Institute of Stockbrokers and Chartered Institute of Accountants of Nigeria and the rest), suspended their examinations slated for March and May respectively.

Similarly, on 18 March the government placed a travel ban on thirteen countries with high cases of the virus, and also ordered the closure of all land borders for four weeks. Based on the above, about 30 states reacted by closing their sea, air and land boarders allowing only vehicles carrying food items, medical supplies and patients to have access to the states. The Nigerian Railway Corporation also responded by suspending all passenger services from 23 March.

Corporate entities were smart enough to announce partial closure of their offices and staff were asked to telework from home. It is envisioned that remote working may become the new style of working as corporate firms in Nigeria begin to consider the benefits of teleworking. Similar reactions were recorded in the sport-space as the Nigerian Football Federation suspended all football activities for four weeks, and the 20th national sports festival slated for 22 March to 1 April in Benin City was postponed. The Chief Justice of Nigeria, Tanko Muhammed ordered all courts in Nigeria to shut down from 24 March, and the Independent National Electoral Commission announced suspension of all activities in fourteen days. The entertainment industry aligned with prior responses as Actor Guild of Nigeria banned movie sets across Nigeria indeterminately.

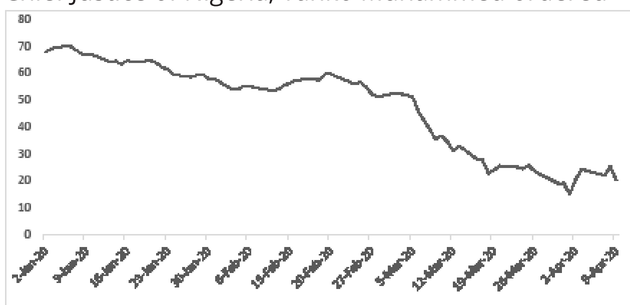

Figure 1 Daily Price of Brent from 02 January 2020 to 09 April 2020
Source: Countryeconomy.com

The Impact of the Pandemic on Nigeria

The advent of the pandemic has affected every sector of the economy. Meanwhile, few of the impacts of the pandemic on the Nigerian economy are summarized below:

Oil Sector

The emergence of COVID-19 has led to a dramatic fall in crude oil prices. For instance, the price of Brent crude was just over $26 per barrel on April 2 compared to over $60 it was sold for prior to the pandemic. With crude oil accounting for about 90% of Nigeria's exports, the decrease in oil prices will adversely affect the volume and value of Nigeria's net exports. Consequently, the petroleum sector of the economy will record a downturn in profit as a result of the unprecedented emergence of COVID-19. Figure 1 below is price of Brent from 02 January 2019 to 9 April 2020.

Budget

Nigeria's 2020 budget was significantly tie to revenues from sales of crude oil with a projected inflow of N8.24 trillion, showing a 20% increase when compared to 2019 figure. The revenue expectations were premised on production of 2.18 million barrels per day, stable market price of $57 per barrel and expected increase in global demand for crude oil. The emergence of COVID-19 has led to a review of prior revenue projections and fiscal outlook as government adjusted its projected crude oil price of $57 to $30 per barrel, whilst production of 2.18 million barrels of crude oil per day remains constant. According to the Minister of Finance, Budget and National Planning, Zainab Ahmed, the Federal Executive Council has approved a 20% reduction in capital budget and 25% cut in recurrent expenditures. Similarly, the Federal Government has also cut down on the size of federally funded upstream projects of the petroleum sector, and adjusted its customs revenue which was previously budgeted at N1.5 trillion. Accordingly, projected revenue from privatization proceeds were reduced by 50% due to the slowdown in economic activities.

Zainab Ahmed had earlier warned that Nigeria may slip into recession if COVID-19 pandemic lingers for 6 months. Consequently, experts have supported the Minister's projection based on the unprecedented sharp drop in global crude oil prices (Nigeria's main source of income) to below $30 per barrel, with projections that it will dip further going by the price war amongst key players in the industry amid the pandemic. It is believed that, the country may not escape economic crunch as economic indicators nosedive.

Productivity

The lockdown of businesses and movement of persons has affected production of goods and services. Since the informal sector which contributes about 41% of the country's Gross Domestic Product (GDP) does not have the facilities to work at home like some Companies in the formal sector of the economy, the "work from home" policy may not apply to artisans, and other crafts. In the formal sector, remote working may not apply to unskilled workers and workers whose work does not require the use of computers. Expectedly, GDP for the first and second quarter of year 2020 will plunge due to the shutdown of industries, businesses, corporate firms and some

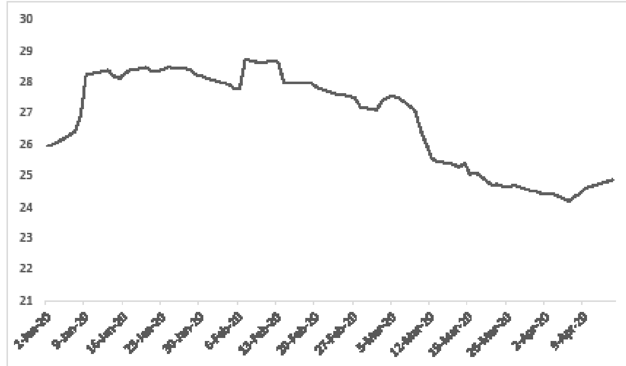

Figure 2 Daily Market Capitalization (N'Trn.) from 02 January 2020 to 14 April 2020

Source: Nigerian Stock Exchange (Daily XDB Report).

government offices. In the same vein, the emergence of COVID-19 will aggravate the unemployment situation in Nigeria as the Minister of Finance had announced government's decision to stop recruitment, except for essential services like security and health services. Previously, the National Bureau of Statistics' (NBS) report ranked Nigeria 21st among 181 countries with unemployment rate of 23.1%. The country has also been rated as the poverty capital of the world with an estimated 87 million people living on less than $2 per day threshold. With the embargo on recruitment, we foresee a dramatical increase in poverty, violence, youth unrest and unemployment in Nigeria.

Financial Market

The Capital Market is on a free fall trajectory due to the pandemic. For instance, the Nigerian Stock Exchange recorded a loss of N2.3 trillion in the three weeks after Nigeria's first case of Corona Virus. Currently, uncertainty is a big factor in the financial markets with attendant implications for the real economy. As investors lose money and businesses lose capital, spending by both households and firms will decline. Figure 2 is the daily Market Capitalization from 02 January 2019 to 14 April 2020.

Foreign Exchange

The pandemic has also led to a sharp drop in the value of the Nigerian currency (Naira) relative to the U.S. Dollar. The Naira which has remained relatively stable at N360/$1 since mid-2017 has plunged to N430/$1. This drop is due to the activities of bureau de change operators hoarding Dollars, and speculators attempting to hedge against potential loss in the event of devaluation. Nigeria's economy is import dependent, hence scarcity in the supply of Dollar affects most businesses that require Dollars to fund importation of goods. Facing the reality of the moment, the Central Bank (Apex Bank) sold Dollars to banks at N380/$1, whilst banks trading at the Investors and Exporter (I&E) window bought Dollars at N360/$1 from the Central Bank compared to the prior price of N307/$1. With the Naira falling against the Dollar, foreign investors are hesitant to hold naira-denominated assets and therefore selling off their naira assets.

Interventions

To cushion the effect of COVID-19 on the economy, the Apex Bank has resorted to quantitative easing techniques, by reducing interest rates on all its' applicable intervention facilities from 9% to 5% per anum for one year effective from 01 March 2020. The Apex Bank has also provided 50 billion Naira ($138.89 million) credit facility for households and small and medium enterprises with extension of the moratorium before payment of principal by one year. The health industry also benefited as the Central Bank gives a 100 billion Naira ($277.78 million) loan to hospitals, healthcare practitioners and pharmaceutical companies in need of loan facilities to strengthen their operations. Similarly, the Apex Bank also gave a 1 trillion Naira ($2.78 billion) to the manufacturing sector as loan. Meanwhile, the Central Bank has granted deposit money banks leave to consider temporary and timeline restructuring of the tenor and loan terms for businesses and households most affected by the pandemic.

Aside government and the Apex Bank's effort to cushion the effect of the pandemic on the economy, corporate organizations, religious bodies, non-government organizations and spirited Nigerians have contributed in cash and kind as well as relieve/medical materials to flatten the COVID-19 curve in the country. Some international bodies have also supported the country with technical aids that may prevent the country from sliding into recession. The media has also played an invaluable role of educating the public, monitoring and reporting of events around the pandemic.

Further to the above, the United Nations through its' humanitarian partners has installed hand-washing stations in Internally Displaced Persons (IDP) camps and ensuring supply of clean water. Partners are also distributing soaps and teaching women how to produce their own soaps. The United Nations team has developed messages, posters, videos and other communications aimed at increasing awareness about COVID-19 among IDPs and other vulnerable persons in the northeast. Sensitization campaigns are also reaching millions of Nigerians in various states through partnerships with major television stations and radio channels in the country.

Future Outlook

Experts have envisaged economic recession as a result of the COVID-19 outbreak. This is explained by predicted decline in household consumption due to economic hardship, hence, consumers will only spend on food and other survival items. Expectedly, corporate firms will embark on salary cuts and disengagement of staff as a result of a decrease in revenue and uncertainty in the economy.

Taking into consideration the uncertainty that is connected with the pandemic and the negative profit outlook on possible investment projects, firms are likely to hold off on long-term investment decisions. This decision may be due to the inability to project how long the pandemic will linger, and uncertainty in government policies during and after the pandemic.

The government is expected to proactively roll out more fiscal stimulus measures to resuscitate the economy. However, this text is not oblivion of the attendant effect of the decline in commodity prices on government's revenue. In the light of this, we foresee the government soliciting support from international communities and approaching international markets for loan facilities.

Conclusion

Further to the above mentioned impacts of COVID-19 on the Nigerian economy, and the subsequent efforts by the federal government, all the thirty-six states, corporate organizations, international bodies, religious organizations, non-government organizations and spirited individuals to fight the spread of COVID-19 in Nigeria, it is expected that the country will triumph over the pandemic, if the "stay at home, wash your hands regularly, do not touch your facials, social distancing, hand sanitization and face-masking" measures are adhered to by Nigerians.

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Growing Africa's Electricity Distribution Demand

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Energy is firmly connected to each and every aspect of human development and to enhance sustainability. In today's world, global solutions are constantly sought for global challenges which are but not limited to energy inefficiency, climate change, environmental pollution, scarcity of natural resources; all of which have resulted from overdependence and excessive usage of fossil fuels. To achieve sustainable development for humanity, the urgent need for dealing with this daunting task is enormous and cannot be overemphasized. Globally, clean energy development has become the pivot of sustainable development in energy production. Interestingly, the electricity mix has been gradually and systematically replacing other forms of energy in energy consumption.

Electricity has been projected to be the alternative for energy consumption by substituting crude oil and its fractionation products, natural gas, coal and firewood. Electricity possess the most environmental friendly distribution mechanism for the modern energy system in the 21st century; a shared interconnected electricity-mix. Therefore, a robust and effective production, transmission and distribution of clean energy sources cannot have come at a better time than now in order to demote carbonization and promote cleaning, electrification and networking. According to the Global Energy Interconnection (GEI) system, the realization of Agenda 2030 including the 'Paris Agreement' to guarantee reliable, clean and affordable modern energy for all is paramount in coordinating societal development, ecological environment and the economy. The Global Energy Interconnection Development and Cooperation Organization (GEIDCO) since 2016 have been looking at energy interconnection schemes at world, continents, regional and country level through systemic researches based on comprehensive data analysis and cognate statistics on the environment, energy and climate, including references from strategic developmental plans and policies of different governments, international organizations, enterprises and research findings from educational and research-based institutions. Accordingly, there have been advancement in technological model tools for studying the key issues that relate to the development of the energy mix, hence a holistic, innovative and systematic approach for global energy transition and clean low-carbon development is needed for energy interconnections across all continents and countries.

In Africa, there exist great potential for electricity generation from clean energy sources (especially solar, thermal, wind and hydro). The key to achieving sustainable development in the continent relies heavily on its abundant natural resources, spurring low-carbon transitions, shaping and bolstering its energy interconnection infrastructure. For electricity to be effectively distributed in Africa, there has to be optimal generation fed into the electricity grid, including changes in markets and regulations that promote energy transitions and are in tune with globalization.

New or changes in existing programmes and policies must be made to enhance electricity interconnectivity and infrastructure across African countries, as most existing policies are still localized. Many African countries today face erratic power supply and countries producing abundant megawatts of electricity could supply to countries with low amount instead of unused storage, hence developing the interconnected electricity market. These could come through a harmonized legislation by all African countries, the African Union (AU) and its regional economic blocs namely; Economic Community of West African States (ECOWAS), Southern African Development Community (SADC), East African Community (EAC), Arab Maghreb Union (AMU), Economic Community of Central African States (ECCAS), The community of Sahel-Saharan States (CEN-SAD), Common Market for Eastern and Southern Africa (COMESA) and the Intergovernmental Authority on Development (IGAD). The objectives of these regional blocs are to attain sustainable growth and development of the member-states by promoting a more balanced and harmonous development of its production and marketing structures; to promote joint development in all fields of economic activity and the joint-adoption of macro-economic policies that will enhance the standard of living of its people, hence achieving cross-border, inter-regional and inter-continental electricity interconnections. Therefore, all clean energy sources must be rigorously and holistically developed into a 'multi-energy mutually supported electricity market system' in Africa that will guarantee diversified and more economic supply. Furthermore, sustainable 'growth strategy' to track electricity supply and for accountability should be adopted; for example, electricity-manufacturing strategy, electricity-consumer strategy and electricity-mining strategy.

Advocating for a coordinated growth through regulations between wind, solar and hydro power that will further promote energy transitions at a regional and continental level is paramount. There is possibility for an increase in the installed capacity of clean energy from 23% to 62% in 2035 and 77% in 2050. These regulations should reflect centralized large-scale energy development bases in conjunction with distribution patterns in areas with high-quality resources and growth conditions for sustainability. For example, abundant clean energy resources abound in Central and North Africa while large minerals resources are found in West and Southern Africa. Clean energy could be harnessed from the Congo River in Central Africa and abundant solar energy from North Africa, both serving as energy bases. West and Southern Africa with high population could serve as electricity load center markets while hydro-power and geothermal energy from the Nile River and East African Rift Valley respectively could meet power demand for the East-African region.

Growing Africa's electricity distribution demand is extremely important in ensuring a robust and effectual energy transition mix, as the political and business environments have gradually stabilized and is continuously improving.

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Regions	Primary energy demand (Billion TCE)			Clean energy proportion in primary energy (%)			Final energy consumption (Billion TCE)			Electric power proportion in final energy (%)		
	2016	2035	2050	2016	2035	2050	2016	2035	2050	2016	2035	2050
North Africa	0.27	0.42	0.52	6	20	42	0.19	0.27	0.32	20	38	51
Central Africa	0.07	0.15	0.23	89	72	71	0.05	0.10	0.14	4	20	28
Southern Africa	0.31	0.51	0.62	33	41	52	0.18	0.34	0.40	18	25	33
East Africa	0.23	0.38	0.53	87	58	59	0.16	0.30	0.38	3	9	17
West Africa	0.29	0.46	0.65	75	66	64	0.24	0.33	0.41	3	19	31

Note: 2016 estimated data according to IEA.

TABLE 1: STATUS AND OUTLOOK OF AFRICA'S ENERGY DEVELOPMENT

Note: 2016 estimated data according to IEA.

Table 2 States and Outlook for Africa's Installed Capacity of Clean Energy

Region	Thermal (GW)			Hydro (GW)			Wind (GW)			Solar (GW)			Biomass (GW)			Geothermal (GW)		
	2016	2035	2050	2016	2035	2050	2016	2035	2050	2016	2035	2050	2016	2035	2050	2016	2035	2050
North Africa	80.43	130.51	120.9	4.97	7.05	7.05	1.91	18	36	0.56	93.37	207	0.07	0	0	0	0	0
Central Africa	1.88	7.21	8.67	4.01	55.61	142.58	0.01	0.48	0.8	0.01	2.05	4.6	0	1.57	3.4	0	0	0
Southern Africa	48.28	70.65	72.8	11.09	33.31	44.01	1.48	18.7	44.9	2.27	47.31	131.08	0.58	3.12	3.74	1.88	0	0
East Africa	4.21	13.9	23.66	23.66	35.78	53.26	0.36	6.92	26.33	0.1	28.45	113.7	0.57	1.84	1.63	0.66	8.3	11.37
West Africa	17.2	45.81	62.62	5.14	21.74	33.28	0.06	8.61	17.44	0.27	43.9	102.23	0.06	8.41	20.77	0	0	0

North Africa: Morocco, Algeria, Tunisia, Libya, Egypt
Central Africa: Chad, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Congo, D.R. Congo, Sao Tome and Principe
Southern Africa: Angola, Botswana, Lesotho, Malawi, Namibia, South Africa, Swaziland, Mozambique, Zambia, Zimbabwe, Madagascar, Mauritius
East Africa: Sudan, South Sudan, Ethiopia, Kenya, Uganda, Eritrea, Djibouti, Rwanda, Burundi, Tanzania, Somalia, Comoros, Seychelles
West Africa: Niger, Nigeria, Benin, Togo, Burkina Faso, Ghana, Cote d'Ivoire, Liberia, Mauritania, Mali, Sierra Leone, Guinea, Guinea-Bissau, Senegal, Cabo Verde, Gambia

COVID-19: Demand and Supply Shock on Energy Sector in India

BY KAKALI MUKHOPADHYAY AND KRITI JAIN

INTRODUCTION

The recent Coronavirus strain, originating in the Wuhan province of China, has rapidly spread across the globe. The pandemic has resulted in the imposition of virtual lockdowns by economies, leading to a situation comparable to the global financial crisis that hit the world in 2007. However, the difference is the uncertainty surrounding the lasting impact and possible action strategy to be taken for maintaining the structural health of economies in which almost all the sectors are affected. Such a crisis hasn't hit the world since the 1920s but the historic measures in today's scenario provide a little relief as the economies are now much more developed and complex. One such sector which has changed significantly and played a crucial role in running the fuels of industries, as well as households, is energy. However, the energy sector has been facing the turmoil of COVID-19 as the consumption baskets and production baskets see a major compositional change to adapt to new circumstances. Energy consumption in India is the third largest in the world, after China and USA, and its production basket is diversified between domestic sources and imports from other countries. This provides a fundamental understanding of how the energy sector is linked with trade and the global economy as well. The fall in energy consumption across India signals the impact of the pandemic in India.

The All-India Energy Consumption has fallen by 22.1% on April 4, 2020, from March 18, 2020, when the restrictions were not imposed fully in all the parts (Table 1). As many states went into lockdown, the fall in consumed energy started happening at an increasing rate till March 26, 2020, after which the rate of change saw a decline but remained much below the consumption levels before lockdown. This change in pattern could be attributed to the clarity provided by the government on the functioning of essential services and increased demand of electricity by the households and hospitals. This moderated the fall in energy consumption but could not compensate for the loss of energy demand by Industrial and Commercial sectors.

The energy exchange i.e., Net Imports with Bhutan, Nepal and Bangladesh reflects the impact on the supply side of the pandemic (table 2).

The fall in energy exchanges with Bhutan might be due to lockdown in both Bhutan and India and consequent transportation bottlenecks. Energy exports to both Nepal and Bangladesh are consistent which implies that exports of energy are happening sufficiently, but imports are less.

Having the above information as a backdrop, the objective of this paper is to analyse the above-mentioned changes through an understanding of various factors influencing energy sectors in India due to the COVID-19 outbreak. It studies the impact of the pandemic on the oil sector, electricity by thermal and renewables sectors. The sectors are chosen for their important interlinkages with the development of core sectors and enhanced focus given by The Government of India in its policy targets.

The study is divided into four sections in which Section 1 is the analysis of the oil sector, followed by Section 2 studying the fall in the electricity sector and Section 3 outlining the impact on Renewable Sector. Section 4 provides concluding remarks and future

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Date	Energy Consumption (GWh)											
	Northern Region		Western Region		Southern Region		Eastern Region		North-Eastern Region		All India Region	
18-Mar-20	827		1187		1148		383		42		3586	
22-Mar-20	734	-11.25%	971	-18.20%	975	-15.07%	315	-17.75%	36	-14.29%	3030	-15.50%
24-Mar-20	695	-15.96%	944	-20.47%	983	-14.37%	314	-18.02%	39	-7.14%	2975	-17.04%
25-Mar-20	665	-19.59%	844	-28.90%	911	-20.64%	320	-16.45%	36	-14.29%	2777	-22.56%
26-Mar-20	628	-24.06%	771	-35.05%	904	-21.30%	327	-14.62%	35	-16.67%	2652	-26.05%
31-Mar-20	623	-24.67%	791	-33.36%	902	-21.43%	326	-14.88%	36	-14.29%	2705	-24.57%
04-Apr-20	651	-21.28%	858	-27.72%	908	-20.91%	340	-11.23%	34	-19.05%	2791	-22.17%

Table 1: Change in Energy Consumption

Source- POSOCO weekly reports (March-April, 2020)

DATE	BHUTAN		NEPAL			BANGLADESH		
	Energy Exchange	Day Average (MW)	Energy Exchange	Day Peak (MW)	Day Average (MW)	Energy Exchange	Day Peak (MW)	Day Average (MW)
[illegible]	4.4	250	-1.2	-284	-53	-13.5	-872	-563
[illegible]	4.1	337	-4.5	-270	-182	-13.4	-882	-558
[illegible]	7.4	300	-1.8	-239	-77	-14.4	-1002	-600
[illegible]	3.2	215	-1.9	-234	-81	-14.4	-1076	-599
[illegible]	6	251	-2.4	-216	-101	-14.3	-1058	-595
[illegible]	4.3	270	-2.7	-275	-112	-12.4	-1027	-528
[illegible]	3.1	217	-2.3	-289	-119	-13.7	-1072	-571

Table 2- Change in Energy exchange with Bhutan, Nepal and Bangladesh

Source- POSOCO weekly reports ((March-April, 2020)

scope of the study.

ANALYSIS OF OIL SECTOR

Presently, India is the third-largest consumer of crude oil and petroleum products in the world. Its consumption basket for raw crude oil is largely import driven constituting 82% of the total and it aims to bring it down to 67% by 2022 through various alternative mechanisms. At the same time, India is the largest exporter of petroleum products in Asia and the second-largest refiner in Asia. COVID-19 shutdowns and global scenarios have seen a new trend in the oil market where the demand has slumped by 70% equating to 3.1 million barrels a day of lost demand (Bloomberg, 2020), creating a glut in supply markets.

Supply-side shocks

India's imports are in the form of Brent crude oil (25% of total) and a mix of Oman and Dubai crude (75% of the total). Recent oil market disturbances are bred through failed negotiations between Saudi Arabia and Russia, consequently resulting in the commitment of possible increased supply in the future. While Saudi Arabia is India's biggest oil partner with supply worth $21.2 billion, Russia's value stands only at $1.2 billion (Workman D, 2020). This global change along with the pandemic has brought down the oil prices to a new low at $30/ barrel from $70/barrel. However, recent negotiations of OPEC+ have shown positive signals which could imply that oil prices might moderate in the long run but the possibility of shooting up to high levels is less as demand will be comparatively lower till COVID-19 cases subside and final commitments are made by major oil-exporting companies.

Demand induced slowdown

The pandemic has disrupted the demand markets for oil due to the reduced exports and lower domestic demand for oil because of shutdowns, especially air travel, Indian Railways, transport and logistics sector. The consumption of petroleum products has fallen to abysmal 0.21% in 2019-20, of which 18% fall occurred in March 2020 (Ministry of Petroleum and Natural Gas, 2020). In addition to this, the largest consumed liquid fuel in transport sector i.e., diesel saw a decline in consumption by 24.3% in March 2020 as compared to March 2019 (The Mint, 2020). This could be due to reduced demand by already stressed automobile sectors as they switch over from BS-IV engines to BS-VI. Further, Consumption of Aviation Turbine Fuel (ATF) declined 32 per cent to 484 TMT (Thousand Metric Tons) in March 2020, as airlines ceased operations due to lockdown measures announced by major economies around the world.

The Indian markets have not benefitted from reduced prices due to taxation laws where the Government has increased the excise duties resulting in no transmission of these prices to consumers. This has inhibited the possibility of both price-driven demand and growth-driven demand. Due to the above, imports of oil have fallen to 225 million tonnes (MT) in FY20 against 227 MT in FY19, resulting in 6% fall of import bills (PPAC, 2020). Reduction in oil import bills provide additional fiscal space to the government but poses a challenge for oil and gas companies running in India. The best performing states in terms of oil and gas companies are Maharashtra, Tamil Nadu, Telangana, Delhi, Madhya Pradesh and Gujarat (India Investment Grid, 2020), which are also among the worst affected by the outbreak. The companies might face financial distress in paying off existing debt covenants and take a prolonged period to recover as the sectors dependent on it for supply might pick up the differential pace for recovery.

However, the current situation provides incentives for boosting diversification of its oil procurement and building up strategic reserves for the future. Fiscal efficiency plays an important role in planning for the post-COVID-19 world. The saved import bills could be used to provide fiscal stimulus package to oil and gas companies and help the commercial users like transport industries to bring down their input cost. In the long-term, investments in cleaner fuel such as indigenous ethanol should be made to reduce oil dependency and achieve Government of India's policy target of lowering import dependence in oil to 67% by 2022.

FALL IN ELECTRICITY SECTOR

The electricity sector has seen visible impacts post-COVID-19 due to the effects on its supply chain and major compositional shifts in demand.

Supply-side shocks on the generation of electricity

Although India has been rapidly trying to expand the share of renewable energy sources in the generation of electricity, conventional sources like coal and lignite based thermal power plants still account for 55.2% of the total (Ministry of Power, 2020). The imports of coal for power which grew at 12 % FY19, declined by 27.5% in March 2020 (Bloomberg Quint, 2020) due to the lockdown. The majority of imported coal has been from pandemic hit countries, where 60% is from Indonesia, 22% from South Africa and 5% each from Russia and Australia (The Hindu, 2020). Given the uncertainty about the retreat of these pandemic measures, India's coal imports might further decline in the coming months, which would imply relying on domestic production.

The coal which is classified as essential has registered record production of 2.56MT per day (Money Control, 2020) by Coal India Limited. A Buffer of 107 MT of coal stock would suffice the short-term demand but, the long-term capacity expansion is a challenge. The reduced global demand would pull down coal prices, leading to a fall in the valuation of the mines and loss of revenue for the government in the sale of coal mines as per recently launched Open Bidding Policy. In addition, the pandemic might also reduce FDI in this sector. The domestic capacity expansion will also be challenged as coal-based plants are dependent on Chinese power generation equipment manufacturing such as Dongfang Electric, Shanghai Electric and Harbin Power, which have been severely hit by closing down of Chinese markets (The Mint, 2020).

Demand induced slowdown

Although relaxation and deferred payment options have been provided for the procurement of coal by power-producing companies to reduce the immediate financial stress on companies but, the demand for power has reduced. The plants which were operating at 80-90% capacity are now operating at about 50-55% (Bloomberg Quint, 2020a). This could be due to reduced consumption from 110.33 billion units in March 2019 to 100.2 billion kilowatt-hours in March 2020 (POSOCO, 2020). It has been observed that the largest fall is seen in states of Punjab and Haryana, which could be due to reduced irrigation driven consumption. The industrial and commercial consumers account for almost 50% of India's power demand which has been shut down due to lockdown, resulting in a 10.4% fall in dispatches of coal (The Hindu, 2020). This might result in the creation of coal stock for the companies but distress in terms of loss of revenue as the entire power supply chain gets disturbed.

On the transmission and distribution side, the state electricity boards operate under cross-price subsidy policies wherein high tariff rates for commercial and industrial sector subsidises the retail supply of electricity i.e. households. The increased household consumption due to work from home and requirement of uninterrupted supply to hospital and care centres for 24*7 operations of ventilators and machines have increased the retail demand but not as much to compensate for the commercial losses. This will impact the financial health of these companies and, reduce their investment and employment capacity in the long run. Distribution Companies' (DISCOM) total dues have increased to ₹80,345 crores in February'20 from ₹76,150 crores in December'19 (PRAAPTI, 2020). Aggregate Technical & Commercial losses (AT&C) for these companies have increased from 18.2% FY19 (PIB, 2020) to 19.02% at present (UDAY, 2020). Given the fall in demand, these losses could go up. This along with change in demand patterns, would impact the financial health of the generating companies and increase the fiscal burden of the state governments as electricity charges are highly subsidised across nations. If the companies start charging higher tariffs in future, it would increase the already COVID-19 hit industrial sector and household expenditure on electricity, constraining the government's Sustainable Development Goal of 24x7 i.e. accessible, affordable, reliable, sustainable and modern energy for all. Stockpiling of coal might compel sustained electricity production in future, hampering the achievement of Nationally Determined Contributions (NDC) targets under Paris Climate Agreement 2015.

IMPACT ON RENEWABLE SECTOR

In 2019, the government announced the target of achieving 175 GW of installed power capacity from RES, primarily from solar (100 GW) and wind (60 GW) energy by 2022. At present, the share of RES in total installed capacity is 22.9% and it is expected to increase to 36.4% by 2022 (CEA, 2020), which might not follow the same trajectory due to COVID-19 supply shortages and low demand from the power sector.

Supply-side shocks

Currently, RE is largely cornered towards the generation of electricity via micro-grids or solar-rooftops, but their expansion has been challenged by COVID-19 resultant supply chain blockades and inability to procure raw materials from foreign sources. The reliance of Indian Solar Industries for module glasses and wafers is about 80% (Power Technology, 2020) but the work restrictions imposed in China, delays in production, transportation & logistics would have considerable impacts in the medium term as the trade would take months to reach back to precedent levels. This might increase prices for the solar cell's setup, adding to the fiscal burden of government who provide subsidies on it and delay the capacity expansion. Industries would face the risk of higher cost and delay in payments and their commitments to the power supply. The small-sized rooftop sector players rely on regular supply and have limited inventory capacity and account for 75% of the total market (MNRE, 2020). These small companies may exit the market, reducing market competition which has been the main target in Indian Economic Survey 2020.

At present, India is the world's fourth-largest onshore wind market with 38.06GW of wind capacity (MNRE, 2020). The pandemic would delay the setup of new plants and expansion of the existing plants due to challenges of land acquisition, grid unavailability, supply chain bottlenecks and a lack of project financing. However, India, in this case, is self-sufficient in manufacturing the wind components but the delay in construction activities, transportation lockdowns and states' withdrawal from financing the projects would increase the costs of the projects and financial stress of these companies.

The worst-hit states by the pandemic are the ones leading in solar and wind energy generation (MNRE, 2020) capacity in 2019 (4,880 MW of solar and 24,949 MW of wind capacity). Since renewables are under essential industries, the operations of existing plants might not be impacted but it will affect the projects in development due to restriction on movement. According to Wood Mackenzie's Report (2020), India might face 21.6% or 3GW of solar PV and wind installations being delayed as a result of the lockdown. The current support measures taken by the government to mitigate the downturn might help in the immediate short term but if the situations escalate, there would be a severe financial impact on utility companies.

Demand induced slowdown

The power demand shortage might affect the financial health of distribution companies who procure renewable Net Metering System. The government instructions to DISCOMS to compulsorily purchase power from renewable energy might not dampen the already low demand, but low prices and unlikely immediate increase in demand might hamper RE generators to operate at economies of scale. Total installation of rooftop capacity in 2019 has been 1700 MW, out of which 90% constitute Commercial and Industrial Segment (MNRE, 2020). Most of these industries are shut down including the educational institutions and government offices which also form a major share in the installation demand for solar. The unused generation capacity would leave these setups underutilised, increasing the cost for power companies, uncertainty in jobs and financial insecurity. Even though the hospitals, pharmaceutical companies and other running essential services might be incentivised to make up for the fall in demand in the short term, if the lockdown persists further, situations might worsen in the long term. Further, the installation of residential rooftop capacity for solar may as its demand does not form a regular part of the consumption basket.

CONCLUDING REMARKS

COVID 2019 will impact the energy sector in the long run depending upon the severity of the pandemic in the coming month and how quickly prices become stable. At present, India's cases are rising but it is performing relatively better than other countries. If the cases stabilize and lockdown is revoked in a shorter period, the country would be able to utilise its available stock but, if it persists for a longer-term, say 4-6 months, then the energy sector

Sector		Short term	Long term
Oil		Positive: Savings on import bills	Negative: Financial burden on Oil and Gas Companies
Electricity -Non-Renewable	Imports of coal	Negative: Reduced due to low demand	Positive: Fall in prices and capacity expansion
	Generation of electricity	Negative: operating at 40-45% less than total generation capacity	Negative: restructuring required to meet increased demand and financial stress
	Transmission and Distribution	Negative: Low demand and Existing high debt	Negative: Financial stress
Renewable	Solar	Negative: Low demand by DISCOMS	Negative: Heavy dependence on China for inputs
	Wind	Negative: Low demand by DISCOMS	Positive: Exports and Capacity Expansion at economies of scale

Table 3: Impact of COVID-19 on energy sector
Source: Author's assessment

may face a shortage of inputs. Based on above, assessment is provided in Table 3.

It will also depend on how the global pattern follows as India is dependent on other countries in terms of trade. The present crisis challenges India's long-term commitment to achieving 5 trillion-dollar Economy and sustainable development goals as the slowdown would impact the social factors as well. To address the issue of energy security in the long term, this provides opportunities for import substitution production rather than relying on Chinese markets. This might boost the Make in India initiative, especially when the markets have been provided with natural shields from foreign at present. India could cap on its experience and expand its domestic production and look for a potential trade with unexplored markets who are facing constraints due to shortage of supply from China. Raising funds through renewable bonds and boost to the renewables would help in channelizing savings in the long term while reducing the government's burden of subsidising them. This would put India in a better position to achieve its NDC targets and sustain improved environment conditions such as pollution post-COVID-19, which has been a major problem for the country. Air quality in India's major industrial cities has improved by up to 60% compared to last year (ET Energy, 2020). These could be taken as a positive externality in environmental terms where money could be saved in pollution abatement programs and using the same at investing in cleaner energy sources and financing of projects promoting cleaner fuel. The pace of recovery would depend on the efficiency of social infrastructure and investment climate supported by government's future policies. The short-term implications have been made based on the stock availability and performance of sectors in the immediate past. Modelling exercise would provide further insight into the effect of COVID-19 shock in the economy for the long term.

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COVID-19 and the Power Industry Response: the Case of Kazakhstan

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Introduction

Kazakhstan is a post-Soviet state with a population of 18.7 million living in a vast territory equal in size to Western Europe. However, the high level of urbanization concentrated in four major cities, large trade activities with China, non-visa regimes with Russia and neighboring Central Asian countries, and significant international business travel and tourism (i.e., about 95 thousand Kazakhstani travelers) have made the country highly exposed to the spread of the coronavirus (Kazakhstan government 2020a).

The government of Kazakhstan adopted its first measure to prevent the spread of coronavirus on 8 January 2020 by imposing medical controls on the border with China as well as restricting flights and canceling tourist visas for citizens of countries with the coronavirus epidemic. Such measures allowed Kazakhstan to mitigate the effect of the Wuhan coronavirus outbreak and to report zero cases of coronavirus during January-February 2020 (Kazakhstan government 2020a). However, the rapid escalation of the number of coronavirus patients in Europe forced the Kazakhstan government to adopt drastic measures and declare a one month national emergency from March 16th, 2020 (Kazakhstan president 2020a) with further full lockdowns from March 19th 2020 of its two main cities – its capital, Nur-Sultan, and financial center, Almaty (Kazakhstan government 2020b). From 4 April 2020, the local authorities of other Kazakhstani regions announced similar measures to respond to an increased number of COVID-19 cases (Kazakhstan government 2020c).

The preventive measures of the Kazakhstan government have resulted in minimizing the number of coronavirus cases with 1199 confirmed cases of the virus and 14 confirmed coronavirus deaths as of 14 April 2020 (Kazakhstan Ministry of Healthcare 2020). While the short-term effects of the Kazakhstan government's coronavirus policies have had minimal supply-side effects with no reports on related power supply disruptions, the sector has experienced moderate demand-side effects through the rapid contraction of economic activities. Additionally, the coronavirus pandemic has had an indirect impact on Kazakhstan power industry through transformation of its socio-economic environment and the government response policy. Finally, the rapid evolution of COVID-19 from a local outbreak to the global pandemic indicates a high likelihood of significant long-term implications for the electricity industry of transitional and developing economies.

1. Coronavirus pandemic and Kazakhstan economy

Kazakhstan is an upper middle-income country (per capita GDP US$ 9,300 in 2018) where the industrial activity is dominated by oil and gas production, energy-intensive mining and metallurgical industries as well as coal fired power generation. The coronavirus pandemic and the global economic developments to the COVID-19 have four major economic challenges for the Kazakhstan power industry: increased unemployment, devaluation of local currency, economic decline and government economic sector response.

Unemployment

The absence of a vaccine for COVID-19 has resulted in physical and social-distance policies imposed in the form of lockdowns to prevent the spread of coronavirus. These lockdowns have negatively affected about 81 percent of the global workforce and skewed towards low-income workers and small businesses (ILO 2020). Forecasts have estimated that the first phase of the battle to contain COVID-19 in Kazakhstan could result in more than 3 million people applying for special state benefit programs because of temporary or permanent layoffs (Kazakhstan President 2020b). Because of the losses of work or shutdown of businesses many people face challenges to meet their daily needs for food and medicine and pay their monthly accommodation and utility bills. As a result, both electricity tariffs and disconnections for electricity debts have become politically and socially sensitive issues during the emergency and the imposed lockdown.

1.2. Devaluation of local currency

The COVID-19 pandemic has become not only a threat to the health of Kazakhstan's people but also an economic challenge for oil exporting economies that are faced with the additional shock of oil demand contraction as a result of the economic slowdown and global lockdown restrictions. The demand shock is compounded by supply issues. Hence, since the beginning of the year, oil prices have fallen by 65.7% with forecasted Kazakhstani oil production during 2020 being reduced by 4 million tons to 86 million tons. Moreover, the prices of metals have decreased by an average of 15.6% (Kazakhstan Ministry of Economy 2020a). Both the oil and metal price shocks have caused the Kazakhstan currency to depreciate by 17% (from 382.59 KZT in January 1st 2020 to 447.67 KZT per dollar in April 1st 2020) despite a US$1.487 billion currency intervention by the central bank in March 2020 (Kazakhstan National Bank 2020a, Kazakhstan National Bank 2020b).

1.3. Economic decline

As the result of reduced demand in global markets, Kazakhstan's exports will decline by US$16.3 billion to US$35.1 billion and imports will decrease by US$7.5 billion to US$26.6 billion. Kazakhstan's GDP is expected to decrease by 0.9% with forecasted annual inflation between 9 and 11% (Kazakhstan Ministry of Economy 2020a). The losses on revenues of the country's budget are estimated at US$3.8 billion (Kazakhstan Ministry of Economy 2020b). To cover the shortfalls in budget revenues and to finance the anti-crisis state program, Kazakhstan's government intends to increase the guaranteed transfer from the National Fund (i.e., the country's sovereign oil fund) from US$4.7 to US$10.6 billion and borrow additional US$3 billion in foreign capital markets (Kazakhstan Ministry of Finance 2020).

1.4. Economic response of Kazakhstan government

To the combat negative implications from COVID-19 pandemic Kazakhstan's government has launched an unprecedented economic response by offering a special state benefit programs for up to 3 million unemployed as well as a 10% annual raise for pensions. Furthermore, small and medium enterprises have been granted a three-month suspension for their tax payments. The agricultural sector will be provided with state loans and fuel subsidies for farmers equal to a 15% discount on market prices. In addition, the government has initiated electricity tariff reductions (Kazakhstan president 2020b). Finally, local authorities in some regions have requested not to apply disconnections for nonpayment of services or granted deferral of payments (Kazakhstan akimat 2020).

2. Kazakhstan power industry under COVID-19 pandemic

One of the distinctive features of the power industry response to the coronavirus outbreak is the need to address simultaneously two critical priorities of power infrastructure: 1) to ensure the safety of their employees; and 2) to provide reliable energy supply to their customers.

2.1. Employees' safety

The protection of the lives of employees during coronavirus pandemic is the priority in any industry (WHO 2020). However, the power industry has faced several challenges with the adoption of all safety recommendations. The first measure of Kazakhstani power companies, similar to other industries, has been to improve the personal safety of their employees by providing correct information on COVID-19, distributing protective equipment, and increasing on-site cleaning. The second measure has been to ensure social distancing. This has resulted in meter reading, customer-centers and distribution of monthly billings being temporarily suspended. Despite both measures, the power industry has had problems with the adoption of distance working practices since only administrative support teams can work from home. While modern electronic systems of operation and control could potentially decrease the level of physical presence in the power industry, the existing power industry technologies, dominated by Soviet-designed coal-fired generation, has low levels of digitalization that prevent remote working practices by the majority of workers in the power industry.

Finally, while manufacturing companies in China, Europe and USA have adjusted their production levels to work below capacity or even temporarily closed their production to minimize risks for their employees (Campbell 2020) and some large Kazakhstan mining companies have developed plans for pre-emptive suspensions of one or more operations (Kazatomprom 2020a), similar temporary decreases of production or shutdowns in the electricity sector would impact the reliability of energy supply. Therefore, virus-related shutdowns in power infrastructure represent major risk threats to reliable electricity supply and should be avoided at any cost during the COVID-19 pandemic.

2.2. Reliability of electricity supply

The most important impact of the coronavirus is the recognition by both policymakers and society that electricity is a "public necessity". First, the public healthcare battle with the COVID-19 pandemic relies on modern medical equipment and requires a reliable power supply. As a result, the most important performance indicator of the work of any electricity company during the coronavirus outbreak is the absence of reported incidents of major power supply outages. In addition, a reliable power supply becomes critical to support not only direct household needs of the lock-downed citizens but also to ensure the operation of other communal services such as heating, ventilation, water supply, fire-protection system, and security. Moreover, state emergency communication, entertainment and social interactions of people during coronavirus outbreak have become heavily dependent on digital infrastructure that is based on a reliable energy supply. Finally, public order and crime prevention are based on street lighting, surveillance and systems of monitoring, which all require a stable electricity supply.

The Kazakhstani government's imposed lockdown can be only effective if the citizens have uninterrupted electricity, water and heat in their apartments and homes. Therefore, any disruption of the energy supply during COVID-19 pandemic may have greater consequences because of increased threats to the health of population and risk of the social instability (in case of disconnection of hospitals, prisons, etc.).

2.3. Financial resilience

The need to provide a reliable supply of electricity requires the financial sustainability of the power industry. In comparison with the service sectors, the power industry has not been affected directly by both the COVID-19 pandemic and corresponding lockdown measures. Nevertheless, the power industry has not been immune to the indirect economic implications of COVID-19 pandemic. First, the power industry has had to address a decrease in power demand from reduced economic activities from a contracted service sector and transportation in lockdown regions. For example, in Nur-Sultan city power demand has dropped after the lockdown by more than 30% from 12 to 8 million kwh/ day (Krivosheev 2020). Second, while the lockdown of the major cities has not changed the overall structure of power demand in Kazakhstan because: 1) mining consumers, the major consumers of power, have not stopped production; 2) government restrictions in lockdown cities did not affect many industries; 3) increased household power demand has partially compensated for the reduction of demand from the service sectors, there has been a growing risk of decline of power demand from energy-intensive manufacturing and oil processing facilities because of global recession (Kazatomprom 2020b). Finally, there is an issue of how to secure the necessary level of power supply revenue stream without deteriorating the living conditions of vulnerable households (Demidov 2020). This is especially important as regional authorities have granted deferral for monthly electricity bills or restricted disconnection for non-payments. Therefore, COVID-19 pandemic represents a challenge to the financial viability of Kazakhstan power industry.

3. Long term implications for the power industry

The long-term implications of the COVID-19 pandemic for the power industry depend upon assumptions of the public health capacity to control the spread of the coronavirus, government measures to stimulate economic activity, public support of quarantine measure, and global economic response. At the same time, the rapid spread of a new virus may become a new reality of modern world because of poverty in the developing world and increased business travelling and mass tourism in advance economies compounded with climate change. A reoccurrence of the COVID-19 pandemic can be expected in case the virus proves to be seasonal, the virus mutates or limited “herd immunity” to the virus (Rossman 2020). In these cases, the COVID-19 virus will have a prolonged impact on the global economy with negative implications on power industry development. Besides, the negative implication of the pandemic may be escalated by geopolitical tensions, inappropriate government interventions, and overreaction of global markets which may lead to wide-scale bankruptcy, unemployment, financial crises, social unrest and political crises (Craven et al 2020). Finally, the situation may be escalated with extreme climate events compounded with disruption of the supply of food, medicine, fuel and energy to become an “ideal storm” scenario.

3.1. Increased government involvement in power markets

The increased importance of electricity supply during an emergency, such as the coronavirus outbreak, and recognition by society and government of electricity as “public necessity” may result in delays with planned market reforms and privatization in power sectors in developing countries and even increase pressure for nationalization and increased state regulation of the electricity sector around the globe. In the situation of an emergency, governments often impose price controls on critical goods and services, and even direct the market (BBC 2020). Moreover, some governments accuse private manufacturers for being non-responsive to increased demand for air ventilators (Netland 2020). As a result, the electricity sector could remain under strict government price regulation or there could be an increased role of the government to maintain control over prices and disconnections by the energy suppliers.

3.2. Economics and power demand

On the one hand, economic crises lead to the decline of power demand and decrease in traditional investment activities. The cancellation or delay of new power projects is expected. Besides, reduced demand for oil may result in a decline of natural gas prices which creates downward pressure on electricity prices even without state intervention. Furthermore, the devaluation of local currencies in oil-exporting economies extends the payback periods of new power projects and reduces the profitability of existing projects with foreign-currency debt financing. Moreover, the economic decline could lead to a high level of unemployment and wide-scale bankruptcy which would deteriorate collection for electricity supply companies.

On the other hand, the coronavirus pandemic will promote consumers and investors to shift to distance learning, working, services, production and consumption. Increased investments into digitalization and adoption of automation could lead to an increase in power demand and increase the requirement to the quality of the power supply.

3.3. Energy security

The COVID-19 pandemic has been characterized by minimal international cooperation, unilateral restrictions by many countries of international travel and trade, intense competition between the large economies for medical equipment, protective gear and medicine, and increased defaults from foreign suppliers to meet their commitments to third countries (Efrati 2020). Besides, many developing countries have had to respond to the coronavirus outbreak by using their limited domestic medical capacities without any significant international support (Bradley 2020). As a result, the traditional debate on energy security may be intensified with increased empirical evidence of the importance of self-reliance, the need for adequate domestic capacities and failures of international cooperation during a critical situation such as the coronavirus pandemic.

3.4. Renewable energy

An increase of state intervention in the electricity market and high demand from the digital sector for reliable power supply may increase the role of traditional generation (i.e., coal-fired) and reduce the focus of the government on promoting renewable energy. At the same time, the increased demand from the consumer side (i.e. IT and telecommunication firms, households, farmers, etc.) for renewable energy self-generation and accumulation of energy can be expected because of a stronger preference for energy autonomy.

3.5. Climate change

Due to reduced economic activity as the result of the economic crisis that accompanied the COVID-19 pandemic, environmental issues and particular climate change may be considered as less important for government and public than the reliability of energy supply and economic recovery. Therefore, some policies mandating early termination of coal-fired generation may be delayed. Besides, cheap electricity from existing coal-fired generation and natural gas power plants could be considered as a measure to stimulate the economy and provide energy access to a vulnerable group of consumers. At the same time, the coronavirus pandemic has challenged the capacity of modern society to respond to external shocks and revealed the urgent need for better international cooperation to mitigate common threats.

3.6. Energy reliability

The power companies need to focus on health of their employees and conduct regular testing of workers. Training of additional people for critical jobs (such as control-room operators and maintenance teams) could minimize the impact of the possible quarantine of the personnel on electricity supply. Besides, sufficient inventory of critical spare parts and fuel is needed to mitigate possible disruptions of supply. Moreover, additional contingency plans should be developed to address the possible outbreak of COVID-19 among contractors and delays in construction and major overhauls (Rosatom 2020). Finally there is an urgent need to reinforce the security of the power infrastructure because any power outage may trigger crime and social disorder.

Conclusion

The coronavirus pandemic has resulted in about a half of the world's population being under lockdown (Sandford 2020). The combination of self-isolation of the majority of the population and social order can only be achieved if the power industry can provide a reliable electricity supply. Therefore, the security of the power supply becomes one of the most critical but not well-recognized aspects of the battle against the COVID-19 pandemic. Nevertheless, the power sector's employees are not invincible, and they can be affected by the spread of the coronavirus and by this, in turn, reduce the reliability of power supply. As a result, it is critical to protect the workers of the power industry from the virus. In addition, while the power industry is not directly affected by lock-down as other sectors of economy, the financial status of power companies will be affected because of low demand, low collections and rigid tariff control. Therefore, there is a need to reassess the risks faced by the investors in the power industry because of the escalation of the costs of power supply failure as a result of the transformation of electricity from a commodity to a social necessity.

Finally, the COVID-19 pandemic may have long-term impacts on power industry development by challenging the traditional theoretical concepts and policy solutions related to the role of government in electricity sector, energy security, digitalization of economy, and climate change. Therefore, power industry should be ready for a fast transformation to meet the new requirements of post-COVID-19 world.

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Saudi Arabia's Unwinnable Oil Price War Against Russia?

BY MAMDOUH G SALAMEH

The coronavirus outbreak could go into history as the largest destructive event that has hit the global economy since the Six-Day War in 1973. Indeed its impact could prove to be far bigger than both the financial crisis of 2008/9 and the 2014 oil price crash.[1]

Whilst both the financial crisis of 2008/9 and the 2014 oil price crash very adversely affected the global oil economy, the outbreak has paralysed the global economy and brought normal economic activities to a virtual standstill in addition to the immense damage inflicted on the global economy which is yet to be assessed.

2020 started with positive projections that the global economy is set to grow at 3.3% with global oil demand adding 1.2 million barrels a day (mbd) over 2019. But this was not to be. The outbreak changed everything.

The world has never faced such a lethal and destructive cocktail as the coronavirus outbreak, global recession, huge glut in the global oil market and an oil price war in the last fifty years.

Until the coronavirus is completely controlled, the world would continue to face huge challenges on daily basis.

Saudi Arabia Wields the Oil Price War Weapon

History is repeating itself. Since the early 1980s Saudi Arabia has wielded the oil price war weapon three times unsuccessfully.

Early in the 1980s, Sheikh Ahmad Zaki Yamani, the veteran former oil minister of Saudi Arabia, suddenly awoke to Saudi Arabia's need for market Share. He flooded the market with oil causing the oil price to collapse to $10/barrel. It later transpired that the Saudi need for market share was just a cover for a CIA-Saudi conspiracy to expedite the downfall of the Soviet Union with the Reagan administration starting a costly arms race and Saudi Arabia depressing oil prices by flooding the market. Saudi Arabia ended bankrupting itself in the service of the United States.[2]

In the aftermath of the 2014 crude oil price crash, oil prices lost 54% of their value and there were no indications that it will stop there in the absence of a major production cut by OPEC. At one point the price fell to $30.

Countries	2013	2014	2015
Iraq	86	74	55
Kuwait	92	72	54
Qatar	42	34	25
Saudi Arabia	274	208	156
UAE	53	42	31
Oman	27	22	19
Total	574	452	340

Table 1 Net Oil Export Revenues of the Arab Gulf Oil Producer (US$ bn)

Source: U.S. Energy Information Administration's (EIA) 2014 Short-term Energy Outlook (STEO) / Author's projections for earnings in 2014 & 2015.

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See footnotes at end of text.

Instead of agreeing to production cuts with OPEC, Saudi Arabia ignored OPEC and flooded the global oil market with oil. Circumstantial evidence suggested some political collusion between Saudi Arabia and the United States behind the steep decline in oil prices aimed against Iran and Russia.

Saudi Arabia took advantage of the low oil prices to inflict damage on Iran's economy and weaken its influence in the Middle East in its proxy war with Iran over its nuclear programme whilst the United States used the low oil prices to weaken Russia's economy and tighten the sanctions against Russia over the Ukraine.[3] Yet again, Saudi Arabia ended up losing $118 bn in oil revenue (see Table 1). It also sustained huge budget deficits of $140 bn in 2015 and $134 in 2016.[4]

With prices falling by more than 50% as a result of the coronavirus outbreak since hitting £60 in January, OPEC+ met on the 6th and the 7th of March to discuss new production cuts or deepening existing ones. Saudi Arabia called for deeper cuts amounting to 1.0 million barrels a day (mbd) at a time when Libya's oil production had already lost 1.0 mbd.

Russia refused to agree to deeper cuts arguing that they will have no positive impact on oil prices whatsoever while the coronavirus is raging. Russia's position was that OPEC's proposal for cuts of between 600,000 barrels a day (b/d) and 1.5 mbd would have been 'a drop in the ocean' in a market where oil demand is plunging fast. Considering that oil demand is now already down by 15 mbd and could reach 20 mbd in coming weeks, influencing the market with the cuts proposed by Saudi-led OPEC would have been impossible.[5]

Russia's refusal was the last straw for Saudi Arabia so it decided rashly to wage a price war against Russia and flood the global oil market with oil.

The rationale for Russia's refusal is not without merit. Russian oil companies couldn't switch off oil production at their oilfields as easy as U.S. shale oil for instance. Moreover, any cuts will have no impact on oil prices without the United States doing its bit, which it will not. The U.S. shale oil industry has been gaining more market share at the expense of OPEC+ producers.

Moreover, Russian oil companies have always been against any production cuts by OPEC+ arguing that they have invested heavily in expanding Russia's oil production capacity and therefore they wanted a quick

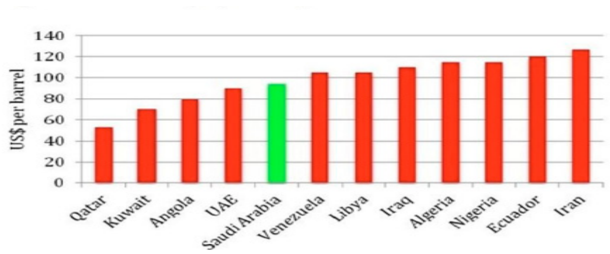

Figure 1. OPEC Median Budgetary Break-even Price
Source: OPEC "Break-even" Prices (Matthew Hulbert/European Energy Review).

return on their investments. They also argued that OPEC+ cuts would have extended a lifeline to a sinking U.S. shale oil industry.

Saudi Oil Price War

Despite the bravado, Saudi Arabia can neither win a price war with Russia nor is able to flood the global oil market with oil for the following reasons.

The first reason is that Russia's economy can live with an oil price of $25 a barrel for years compared with $85-$91for Saudi Arabia's (see Figure 1). Moreover, Russia's economy is highly advanced and well diversified compared with Saudi Arabia's overwhelmingly dependence on oil revenues.

The second reason is that Saudi Arabia doesn't have the production capacity to flood the global oil market with oil. Saudi Arabia has never ever had a production capacity of 12.5 mbd as it claims and will never ever achieve one. So the talk about raising its exports by 3.0 mbd is a farce. Its production peaked at 9.65 mbd in 2005 and has been in decline since.[6] Saudi Arabia can at best produce some 8.0-9.0 mbd with another 700,000 b/d to 1.0 mbd coming from storage. Current Saudi production comes from five giant but aging and fast-depleting oilfields discovered more than 70 years ago.

The third reason is that the lifting cost per barrel of Russia's largest oil producer, Rosneft, is now lower than that of Saudi Aramco. This is due to the falling ruble against the dollar. Russian oil companies earn dollars and other hard currencies for their exports but pay for their operations in ruble. The lower the ruble slides against the U.S. dollar, the lower the production costs of Russian oil companies. As a result, Rosneft's costs per barrel have fallen from $3.1 to $2.5 compared to a $2.80 for Saudi Aramco.[7]

Without the influx of billions of dollars of oil money, multi-billion projects that are deemed vital for Vision 2030 for the diversification of the Saudi economy will be delayed or even shelved indefinitely. Moreover, the economy will not be able to create more than 6 million jobs needed to employ Saudi Arabia's youth. The economy could crash on the back of an oil price war with a mushrooming budget deficit estimated at $116 bn.

To this could be added another loss of $200 bn being a 10% devaluation of Saudi Aramco's shares raising the total to $316 bn. Moreover, the devaluation of Saudi Aramco shares is a major threat as Saudi citizens have been investing not only their own money but also borrowed money from banks to buy Aramco shares.[8]

The stability of Saudi Arabia depends on the Aramco domestic IPO, Public Investment Fund projects and diversification. All can be linked directly and indirectly to OPEC+ and oil prices.

If Saudi Arabia continues with its price war, it could end depleting both its sovereign wealth fund and its stored oil not to mention ending with probable bankruptcy of its economy and destabilization of the country.

The biggest loser in the current situation is the global economy and within the global economy the two largest losers could be Saudi Arabia and the U.S. shale oil industry.

Impact on U.S. Shale Oil Industry

Since its inception in 2008 the U.S. shale oil industry has never been profitable. If it was judged by the strict commercial criteria by which other successful companies are judged, it would have been declared bankrupt years ago.

U.S. shale drillers have been encouraged by easy liquidity provided by Wall Street and other investors to continue production even at a loss to pay some of their debts. In so doing, their outstanding debts have mushroomed to hundreds of billions of dollars leading to large number of bankruptcies among them.

And with a breakeven price ranging from $48-$68 a barrel and a well depletion rate of 70%-90% after first year production, the overwhelming majority of shale drillers can't survive low oil prices let alone a price war.

At $30-35 oil, U.S. oil production could drop by around 1.5 mbd according to Russia's oil ministry. According to Russia, a $45-$55 a barrel is a fair price for oil currently. Such a price range would discourage costly projects and allow demand to grow.[9]

Still, President Trump's administration is under pressure to keep the industry alive even if on life support not only because it is a $7-trillion industry employing more than 2% of the work force and therefore very important for the U.S. economy but also because it enables the United States to have a say in the global oil market along Russia and Saudi Arabia.

Many ideas are being considered for bailing it out including an import tax on all foreign oil imports to the US. One of these ideas sees the United States imposing a fee on imported oil or products. It engenders setting a floor price of $50 a barrel. So if the import price goes down for instance to $30, then an import fee of $20.00 per barrel would be paid to the United States Treasury. Likewise, if the import price is $50.00 a barrel or higher, then no fee is paid.[10]

Calling it a fee doesn't change the fact that it is a tax. It is no more than an opportunistic way to fleece the oil-exporting countries and save American tax payers the cost of bailing out the shale industry.

Impact on Oil Prices

Crude oil prices have more than halved since hitting $60 in January and could be expected to even fall to $20 a barrel with oil majors even preparing for $10 oil.[11]

Saudi Arabia has already announced that it is reducing government expenditures by US$13.2 billion, or nearly 5% of its budget spending for 2020.[12]

Saudi Arabia says it can adapt to today's lower oil prices, but analysts are not buying this claim. Saudi Aramco Chief Executive Amin Nasser even claimed that his company is very comfortable with $30 oil.

At $30 a barrel, the Saudi wealth fund will deplete fast and reduced government spending will stall projects and increase the suffering of the non-oil sector. That's the near-term damage. The longer-term damage is the lack of funds for Vision 2030 which was already going downhill even before the oil price collapse as the promised multibillion foreign investment wasn't materializing. Saudi Arabia could go bankrupt in less than two years if the oil price remained at $30 a barrel.

Globally, the double supply-demand shock in the oil market could lead to companies deferring as much as $131 billion worth of oil and gas projects slated for approval in 2020.[13]

President Trump has been blowing hot and cold about the price war. On the one hand, he threatened to invoke the NOPEC bill to force Saudi Arabia to end the price war. Under NOPEC, the United States could sue OPEC for alleged price fixing.[14] However, this is an empty threat as OPEC is not a cartel and has never been one throughout its history. It won't stand scrutiny in a court of law. Moreover, it is the United States who has been manipulating oil prices for years.

On the other hand, The United States and Saudi Arabia have been discussing the idea of setting up an oil accord, Bloomberg reports, citing U.S. Energy Secretary Dan Brouillette. Such an accord would effectively amount to a cartel, which, by definition, is a group of independent market participants agreeing to act together to influence the market in a way favourable to them.[15] But no decision has been taken yet.

However, for the United States to join Saudi Arabia in a new cartel proves not only that it is a hypocrite but it also undermines the NOPEC bill and exposes the United States' double standards where its interests are involved.

There is, however, a chance to rebalance oil markets if OPEC+ expands to include more producing countries, the head of the Russian sovereign wealth fund, Kiril Dmitriev, told Reuters in an interview.[16] However, this could never work without U.S. involvement which isn't forthcoming. It has become patently obvious that efforts by OPEC+ in the past to deplete the glut and arrest the slide of oil prices are being undermined by the U.S. shale oil industry recklessly producing even at a loss and gaining market share at the expense of OPEC+ members.

Saudis Not Bowing to Trump Admin Pressure to End Oil Price War

Saudi Arabia is resisting pressure by the Trump administration to end the price war according to a report by Aljazeera Satellite Television as quoted by Reuters.[17]

Saudi Arabia's latest move has put Washington in a difficult position. Saudi battle for market share has led to very low prices, but also undermined the shale industry.

A group of six U.S. senators wrote a letter to U.S. Secretary of State Mike Pompeo in the last week of March saying Saudi Arabia and Russia "have embarked upon economic warfare against the U.S."[18]

They called on Saudi Arabia to quit OPEC, reverse its policy of high output, partner with the U.S. in strategic energy projects or face consequences including tariffs, sanctions and much else.

Conclusions

Saudi Arabia risks being blamed for exacerbating the damage to the global economy by its price war. Moreover, by continuing the price war the Saudis are digging themselves deeper into a hole and facing bankruptcy of their economy and a destabilization of their country.

The Saudis have been for years hoodwinking the world about the size of their proven oil reserves and their production capacity and they are now at it again by claiming that they are comfortable with a $30 oil and that they can flood the market with more oil from the 1st of April. Nothing is further from the truth.

Once the coronavirus outbreak is controlled, the global economy particularly China's will behave like somebody who has been starved of food while in quarantine. Once allowed to eat, his appetite will be rapacious and that will exactly be the same with the global oil demand which will probably double or perhaps triple oil imports to compensate for lost demand.

Soon the outbreak will be history with global oil demand and prices recovering all their recent losses.

Footnotes

[1] Based on Dr Mamdouh G Salameh's research and evaluation.

[2] Mamdouh G Salameh, "What Is Behind the Steep Decline in the Crude Oil Prices: Glut or Geopolitics", published in September 2015 by the Arab Centre for Research & Policy Studies in Qatar.

[3] Seyed GholamHosein Hassantash, "Naimi in Yamani's Attire; Are Authorities in Riyadh Witless or Lying? History is Being Repeated", IAEE Energy Forum, 1st Quarter of 2015, p.21.

[4] Mamdouh G Salameh, "Saudi Arabia's Vision 2030: A Reality or Mirage" posted by the USAEE Working Paper Series on 13 July 2016.

[5] Tsvetana Paraskova, "Russia Sees Oil Market Balance in 2021", posted by oilprice.com on 27 March 2020 and accessed on 28 March.

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[7] Tsvetana Paraskova, “Russia’s Unexpected Advantage in the Oil Price War”, posted by oilprice.com on 25 March 2020 and accessed on 27 March.

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[9] Tsvetana Paraskova, “Russia Sees Oil Market Balance in 2021”, accessed on 28 March 2020.

[10] Lourcey Sams, “The Cheapest Way for Trump to Save US Oil”, posted by oilprice.com on 27 March 2020 and accessed on 28 March 2020.

[11] Nick Cunningham, “Oil Majors Are Preparing for $10 Oi”, posted by oilprice.com on 23 March 2020 and accessed on 26 March.

[12] Tsvetana Paraskova, “Saudi Arabia’s Oil Price War Is Backfiring”, accessed on 27 March 2020.

[13]Tsvetana Paraskova, “Oil Price Crash Could Wipe Out $131 Billion in New Projects”, posted by oilprice.com on 24 March 2020 and accessed on 28 March.

[14] Simon Watkins, “Trump’s Ultimate Weapon to End the Oil War”, posted by oilprice.com on 22 March 2020 and accessed on 27 March.

[15] Irina Slav, “Saudi Arabia & the US Could Form the World’s Newest Oil Cartel”, posted by oilprice.com on 24 March 2020 and accessed on 25 March.

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[17] Saudis Not Bowing to Trump Admin Pressure to End Oil Price War”, a report by Aljazeera Satellite TV quoted by Reuters.

[18] Ibid.,

A Nomadic Journey – Simulating the Effect of COVID-19 and Production Shifts on Crude Oil Prices

BY DAWUD ANSARI AND CLAUDIA KEMFERT

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An unsettled market

Concurrent with financial turbulences and collapsing labour markets, the crude oil sector has been witnessing its most severe price drop to date. The slumping prices are a result of simultaneous shifts of demand and supply.

On the one hand, the COVID-19 pandemic has led to a substantial decrease in oil demand, as lockdown measures have put economies worldwide into hibernation. After oil demand growth in 2019 was already below expectations, closed factories are dampening industrial consumption. Closed retailers and cities double down on the demand for goods and services (and, therefore, their production). Oil demand from the traffic sector suffers immensely from remote work and closed international airways.

On the other hand, a showdown between some of the world's largest oil suppliers has led to sudden and ambiguous production shifts. In March, the breakdown of talks on an extension to the OPEC+ agreement finally caused prices to collapse: Saudi Arabia replied to Russia's decision not to participate in further negotiations with a price war. The Saudi oil company Aramco formally announced via the Kingdom's stock exchange *tadawul* that it would supply 12.3 million barrels daily – in January, this figure had still been below 10 million. In April, the OPEC+ group (mainly referring to the OPEC members with the addition of Russia and Mexico) decided to combat low prices and demand with production cuts. The announced measures amount to roughly 10 million barrels daily that shall be withheld by the suppliers to stabilise the market. At the time of writing this article, in mid-April 2020, the announced production cuts have just shown first effects with prices approaching 30 USD/bbl again. Whether a lasting price recovery and or successful implementation of reductions will eventually be achieved is still open at this point.

Simulating supply and demand shifts

We simulate the effects of recent (and potential) supply and demand shifts on the crude oil price to understand current developments and future paths. Our model depicts game-theoretical and techno-economic aspects of the global oil market and is frequently used for scientific publications and policy advisory (see Ansari, 2017; Huppmann, 2013; Zaklan et al., 2018). The simulations use early January as a reference point and estimate (equilibrium) prices for varying degrees of

- a decline in (reference)[1] demand;
- an increase in Saudi Arabia's oil production, as announced in March; and
- production cuts by the OPEC+ group, as announced in April.

The model considers (short-term) profit-maximizing adjustments of other producers, though restrictions ensure that a sufficient rigidity of oil production reflected as well.

Figure 1 visualises the results for combinations of these factors at various degrees. The chart illustrates how the unsettled oil price has been wandering continuously, crossing different situations and levels throughout recent months.

Market conditions in January 2020 (bottom centre in the chart) previous to changes in demand or production led to prices between 65 and 70 USD/bbl. The intensifying decline in demand – initially from the Far East – caused prices to approach 40 USD/bbl (movement upwards in the chart). In the second week of March, Saudi Arabia's announcement to expand its own production by around 20% led to a sudden price slump of about 30% (centre right in the chart). Throughout March, the increasing spread of the virus in Europe (and, later, in North America) led to a further depression in demand for oil. As a result, the price reached 20 USD/bbl and even below in April (top right in the chart).

The figure suggests that COVID-19 has had a far more substantial effect on oil prices than the escalation between Saudi Arabia and Russia. The estimates reveal that a return to the production levels of January 2020 would yield prices still below 40 USD/bbl. A successful implementation of the production cuts announced by the OPEC+ group in April 2020, amounting to roughly 20% of OPEC's production, has the potential to lift prices back to a level of 60 USD/bbl (movement to the left in the chart). However, and besides the question of whether the pledges will eventually be implemented, further demand shifts have the potential to knock the price trajectory off course. Additional reductions of global demand could create excess pressure on the price, which even production cuts could hardly counterbalance (an upward movement in the chart). This case is not unlikely, since oil storages worldwide are approaching their capacity limits, and an end to the Corona crisis is still out of sight. Although China and some European countries are lifting part of their lockdown measures, it is becoming increasingly evident

[1] For a discussion of the difference between reference demand and actual demand, see the Appendix of Ansari & Holz (2019).

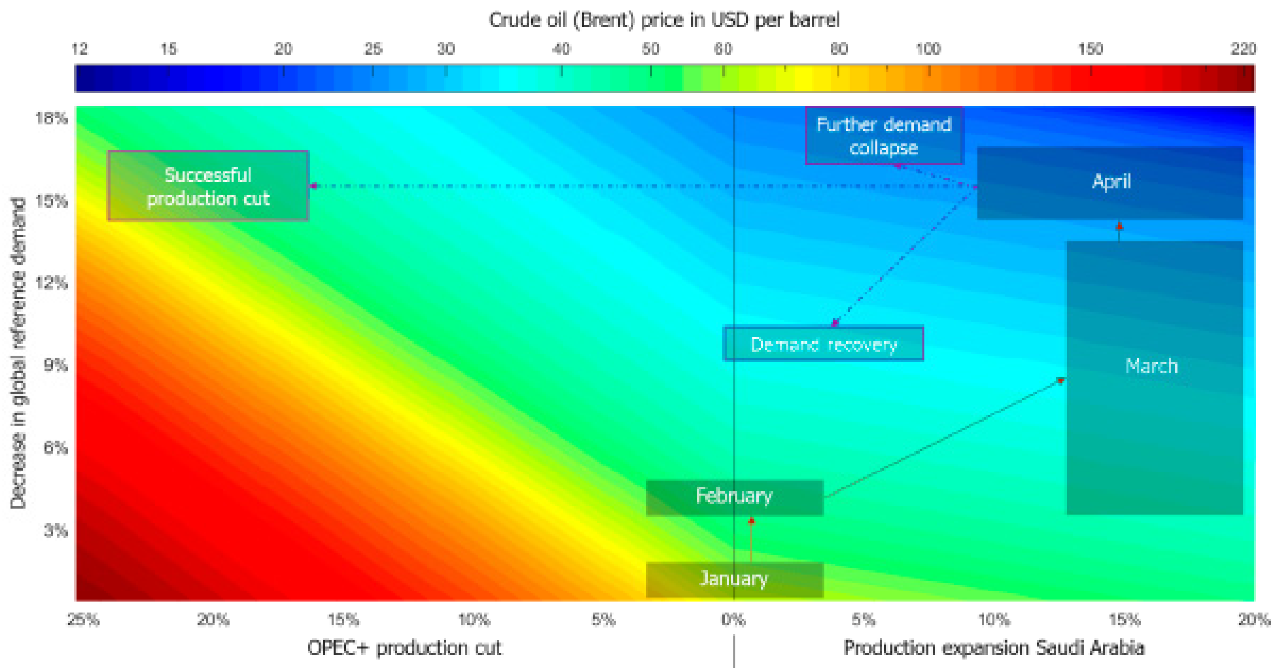

Figure 1: Estimates of the oil price in US dollars per barrel of Brent crude for various levels of an expansion of Saudi Arabian oil production, oil production cuts of the OPEC+ group, and a global decline in (reference) oil demand

Note: Production expansion / cuts and reference demand decline are relative to reference values (early January 2020). Strategic, profit-maximising production adjustments of other producers are included in the values.

Source: Own calculations based on data from Ansari (2017), the International Energy Agency, and the U.S. Energy Information Administration.

that some slowdown of economy and traffic demand might persist throughout the year. In the unlikely case of a sudden demand recovery (downward movement in the chart), prices could return quickly to higher levels, and most of the production cuts would not be necessary after all.

Of course, readers should note that the model is based on static competition, stable demand patterns, and stylised market assumptions. Eventual prices may, hence, differ from the estimates. In particular, the adjustment behaviour of other market participants does not reflect any medium-term changes, for example, due to capacity expansions or shutdowns.

Conclusions

The recent plunge in oil prices results from a drop in demand – a result of the Corona crisis – and an initial failure to conclude a new OPEC+ deal. Although only the simultaneous shift in demand and supply made this rapid fall possible, our simulations suggest that the decrease in demand was the more significant contributor to the developments.

The future price trajectory is mostly uncertain, as both supply and demand trends are still highly dynamic. A full implementation of the production cuts announced by the OPEC+ group has the potential to lift prices back to 50 USD/bbl and even beyond that. However, until now, is not clear to what extent the measures will actually be realised, and further demand shifts can knock the price path off course. Even the announced cuts will not allow exporters to regain ground if oil demand further collapses. Since oil storages around the globe are increasingly filled, this is a strong possibility; and the longer the corona crisis lasts, the more permanent the price effect will be. As long as supply and demand are still exposed to sudden turbulence, the oil price might continue to wander around, waiting for the world to come to rest.

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COVID-19 Effects on the Mexican Oil Sector and the Hedge Fund

BY LILIA GARCÍA MANRIQUE, ISABEL RODRÍGUEZ PEÑA AND MÓNICA SANTILLÁN VERA

Introduction

The coronavirus outbreak resulted in a major global disruption in every economic, social and political sphere around the world. Negative perspectives have plunged the financial markets and the economic outlook for the next years reflects a stagnant world economy. In order to overcome this major impact, most of the world economies have opted for fiscal stimulus, some of which have been as ambitious as 10% of GDP. This inflow of money should be properly allocated within the demand in order to offset the "demand destruction" due to uncertain economic scenarios and job losses around the world.

Even before this major disruption, the oil market was struggling. Tensions between Saudi Arabia and Russia, and lower Chinese consumption resulted in the lowest oil prices since 2016. Now the oil market has to juggle between a global demand destruction and the lowest oil prices in years. With production in a halt in different industries, limited commuting and transportation, lower domestic demand and air traveling almost suspended, even cheap oil prices will not foster consumption. It is accounted that 60% of global oil demand is for transportation and just in the USA there has been a reduction of 50% of gasoline demand.

For the case of Mexico —a minor oil producer but highly dependent on oil revenues—, lower oil prices represent a concerning reduction in fiscal revenues. Besides, given the quarantine in the country, there has been an average reduction of 13.5% in gasoline consumption (SENER, 2020). With a lower oil demand and historical low oil prices, the only strong card that the Mexican oil sector has is its oil hedge. In this context, this article presents a brief perspective of the Mexican oil market and the possible role of oil hedge in future perspectives after the COVID crisis.

The perfect storm

On the last meeting with the OPEC and OPEC+ members (Mexico being part of the latter one), the Energy Ministry opposed firmly against Mexican oil production cuts of 400 thousand BPD. This decision created divided views nationally and internationally. The outcome of this rough negotiation was a total expected cut of 100 thousand BPD and USA will account for the 250 thousand BPD extra that will fulfill the original requested cut plan. From this scenario two factual and underlying issues are clear: the high oil dependency to USA and the uncertain scenario of the Mexican's oil production.

Mexico was a strong oil producer from the 70's to the early 2000's reaching the production peak of 1238 million of annual barrels in 2004 (SIE, 2020). Since then the main oil field, Cantarell, has been in a constant decline without any other relevant oil field discovered as important as this one. During this period the Mexican economy was highly correlated with oil boom and bust following a rent dependent pattern (Puyana, 2015). These shocks can be more clearly appreciated in the ratio of oil rents as percentage of GDP. In 2008 was a total of 10.8% and for the first quarter of 2019 it was 6.6% (Sanchez, 2019).

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See footnotes at end of text.

The decline in Mexican oil production and proved reserves came also with a reduction in refinery capacity and a growing deficit of natural gas. The Mexican refinery utilization rate was of 36% for 2019 (IEA, 2019). Mexico depends on USA refinery power where the former exports crude oil and then imports the final product from the latter. Mexico imports 80% of the gasoline and 65% of its diesel demand from U.S. (IEA, 2019). At the same time, U.S. became one of the biggest producers of shale gas and given its cheap price, the geographical position of Mexico and the environmental benefits of natural gas[1], Mexico became a high importer of U.S. natural gas. . In summary, Mexico became highly dependent of U.S. energy production. This vulnerability and dependency of the oil sector creates an urgency for oil hedge contracts. Although hedging has been common since 2001 (Sarabia, 2019),

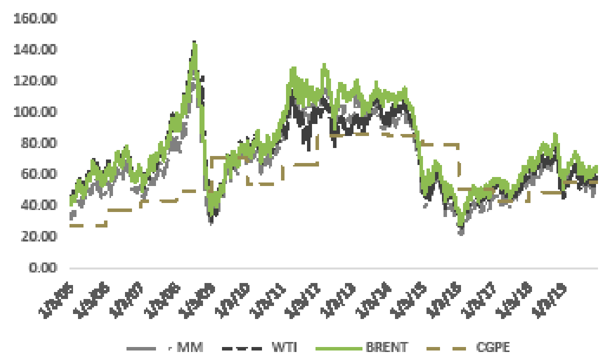

Figure 1: Oil prices in dollars, January 2005- December 2019
Based on IEA and SHCP

in recent years it was harder to buy this insurance given market volatility and lower oil rents. Just this year, PEMEX only manage to cover the total amount of 243 thousand of BPD, last year it was 320 thousand of BDP (Sigler, 2020).

Oil hedge is a low liquid instrument that gives few options to the owner. In previous years when PEMEX wanted to get more liquidity or other options given an overpriced hedge contract, it opted for transactions Over the Counter (OTC), the most common ones being swaps. But in Mexico there is no OTC market, so PEMEX relied on intermediate transactions in OTC international markets. In this regard is clearer why the Energy Minister was so reluctant to accept oil cuts. This may become one of the few years where an overpriced oil hedge is finally paying off to Mexico. Past oil hedge agreements have represented a loss for PEMEX. These hedge contracts also covered for the shocks in WTI prices that impact directly onMexican oil. Figure 1 shows the high correlation between oil prices of the Mexican Mix and WTI[2], as well the General Criteria of Economic Policy (CGPE). CGPE's are the yearly forecast of oil prices that the Mexican government uses to calculate fiscal revenues and oil hedging. Figure 1 illustrates how oil price forecasts fall short given the real prices impacting on oil hedging decisions.

PEMEX after COVID-19

In the present economic jeopardize perspective there are some considerations that Mexico should take into account. First of all, there is a probability that these instruments, either a hedge or an OTC, become insolvent. Issuing institutions may become insolvent and will not be able to pay the coverage in agreement (Gross, 2020). Second, the allocation of these financial instruments will determine the energy policy in Mexico and the World. Given the already imminent governmental intervention with fiscal stimulus (although the first signals from Mexico have been contrary to this trend) it will be worth analyzing where the money will be allocated. In a Global scenario with low oil prices and a substantial global fiscal stimulus, we may see a rebound of oil demand. In this sense there has been a call to allocate any financial instrument, either OTC's or sovereign funds in clean energy options (Saidi, 2020). There is also a call to "nationalize" these financial options. For example, sovereign wealth funds should become more actively domestic by creating domestic partnerships with foreign firms.

Investment will be the key element to achieve economic growth opting for sustainable options although Mexico is opting for a different route. One of the main projects from the present government is a new refinery, Dos Bocas. Even though the main purpose of this project is to reduce energy dependency from the USA, there has been some voices claiming its unsuitability. With lower proved reserves and now, in a low-price scenario, its economic viability is even more questionable. Still in the current situation with investment in halt, any inflow of capital will help the economy. Besides, after hitting one of the lowest prices, the Mexico´s president, Andres Manuel Lopez Obrador, declared it will be suitable to invest in green energies, one of the first positive approach he has had regarding the issue.

The proper allocation of hedge funds or OTC's will be essential to materialize these projects. Either creating stronger domestic partnerships, allocating financial instruments within the country or direct them to greener options. In any other situation the best response could have been investing in low-intense sectors, mainly the service sector, but this time these sectors have been the more vulnerable to the COVID crisis. Even more, their only option may be money inflow from other sectors like the oil market. The energy sector can become the main driver reactivating stagnant investments. This time OTC's and hedge funds not only will transfer systemic risk from market shocks but also from the new Black Swan: COVID-19.

Footnotes

1 Considered as a transitional fuel

2 Not only highly correlated but determined since the WTI price is used to calculte the Mexican Mix Price.

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Are Oil and Gas Prices Immune to COVID-19?

BY KENTAKA ARUGA AND HONORATA NYGA-LUKASZEWSKA

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Coronavirus and global society/economy

COVID-19 pandemic has far reaching consequences for our day-to-day activities. The spread of social distancing which was introduced as a measure to fight the virus influenced our families, work and lifestyles. A survey carried out by Statista (2020) between 26 March and 1 April 2020 on a sample of 2900 respondents from China, Germany, the United Kingdom and the United States supports such impact. It turns out that the majority of respondents (ranging from 73% to 84%) stayed at home after the spread of the coronavirus. By doing so, they have avoided public places (61%-73%), public transport (33%-61%) and worked more from home (28%-39%). A lot has also changed in the shopping patterns. People have either changed shopping hours (30%-37%) or even gave up on standard shopping (61%-76%) by choosing its online form (30%-61%), and additionally as a precautionary measure, decided to use less cash (29%-53%).

World economy seems to be also heavily affected by the COVID-19 pandemic especially in terms of capital and tourists flows. As UNCTAD (2020) forecasts, FDI will suffer from downward pressure between -30% to -40% between 2020-2021. Travel restrictions that were introduced all around the world affected firstly and mostly the airline industry. The world number of commercial flights covering commercial passenger flights, cargo flights, charter flights, and some business jet flights, decreased between January 2020 and beginning of April 2020 from 117,000 to 37,000 (Flightradar24, 2020).

SARS-Cov-2 pandemic is an extraordinary case for the world economy for many reasons. The most important one is the fact that for many years the global economy has not experienced external supply shocks. We have rather been used to negative demand shocks that affected business conditions. The COVID-19 pandemic started with a supply shock on global markets as China was forced to reduce its exports. As a consequence, Chinese exports dropped year to year by 17% between January and February 2020 (Market watch, 2020). However, spread of the virus infected other economies as well. With administratively imposed social distancing measures in many countries, demand weakened and number of companies have been temporarily shut down. In this sense COVID-19 started with a negative supply shock and evoked negative demand response.

Coronavirus and energy sector

Similar supply-demand shock mix can be also observed in the energy markets. The situation we are dealing right now is different from any circumstances we have experienced so far. Firstly, because of the shale gas fever that had transformed the energy markets, both oil and gas, and secondly as this is, one of those critical moments – when the global oil demand in 2020 is forecasted to contract for the first time since the global recession of 2009 (IEA, 2020). This dramatic energy landscape is built upon an on-going dispute between OPEC+ countries and Russia on crude oil supply.

The goal of this study is to check how global COVID-19 pandemic influenced oil and gas prices in the short term. This research is of topic-similarity to the paper of Kelley and Osterholm (2008) who investigated the impact of the influenza pandemic on energy markets. They specifically looked at the U.S. market and the effects for coal supply chains and electricity production. It is understandable that during pandemics electricity production usually plays a role as it is vital to meet the energy needs of society. In this sense country and its inhabitants enjoy reliable and undisrupted energy supplies. At the same time, it is also true that one of the most severe pandemics such as Spanish flu (1918) occurred when hydrocarbons were not that widespread in use. Contemporary disease outbreaks such as SARS (2002) and MERS (2012) were mainly regionally limited, respectively to Asian and Persian Gulf countries. Notable difference was A/H1N1, which spread across the globe in 2009. But swine flu, manifested lower than SARS and MERS mortality rates. The COVID-19 situation could be different because even though the mortality rates are lower than SARS and MERS, it is highly infectious and the virus spread is global.

A closer look at the oil and gas markets between Jan. 23 and March 30 brings the picture of hydrocarbon prices within the COVID-pandemics. In this period, prices of Brent and West Texas Intermediate (WTI) were slumping. The former recorded a drop from 61.26 USD/bbl to 19.07 USD/bbl and the latter from 55.51 USD/bbl to 14.10 USD/bbl (CEIC, 2020). At the same time the reference OPEC basket price decreased from 63.26 USD/bbl to 21.66 USD/bbl (OPEC, 2020). However, the natural gas price did not drop that much. As U.S. Energy Information Agency reports, Henry Hub spot price in the respective period changed from 1.95 USD/million Btu to 1.65 USD/million Btu (EIA, 2020). Therefore, it is substantive to check whether oil and gas prices were affected by COVID-19 outbreak.

Methods and data

To identify if the increasing COVID-19 cases in the U.S. have an influence on the crude oil and natural gas prices, we applied the Auto-Regressive Distributive Lags (ARDL) approach proposed by Pesaran et al. (2001) on number of U.S. and world COVID-19 cases and energy prices. The period investigated in this study is from 21 Jan. 2020 to 30 March 2020. 21 Jan. 2020 is the initial time period when the COVID-19 case became apparent in the U.S..

	Level				First differences			
	PP	KPSS	LS1	LS2	PP	KPSS	LS1	LS2
LnWTI	-1.289	0.217 ***	-4.981	-5.092	-9.263 ***	0.108	-9.573 ***	-10.158 ***
LnBrent	-1.181	0.289 **	-3.896	-4.105	-7.755 ***	0.071	-7.985 ***	-9.384 ***
LnNatural gas	-2.855	0.183	-3.888	-4.778	-6.294 ***	0.047	-6.684 ***	-7.518 **
LnCOVID-US	-0.489	0.218 ***	-3.493	-3.678	-4.690 ***	0.107	-3.310	-6.655 **
LnCOVID-World	-3.613 **	0.179 **	-1.245	-2.712	-4.283 ***	0.282 ***	-5.404 ***	-5.649
LnDJUSAU	-1.935	0.193 **	-3.744	-6.322 *	-6.896 ***	0.081	-7.380 ***	-8.250 ***
LnDWCELC	-2.157	0.178 **	-3.827	-6.010 *	-8.257 ***	0.086	-10.190 ***	-10.190 ***

Table 1 Unit root tests
*Note: PP, and KPSS unit root tests include only a constant and trend ***, **, and * denote significance at 1%, 5%, and 10% respectively. LS1 and LS2 represent the Lee-Strazicich t-statistics with one and two structural breaks.*

The reason of choosing the ARDL method is because this method can be used to identify both short-run and long-run relationships between time series variables when their order of integration is different. For example, the conventional cointegration methods require the variables of interest to be all integrated of order one I(1)), but in the ARDL method the variables can be either I(1) or I(0). Furthermore, ARDL method has its strength in omitted variables and auto-correlation issue in time series data and can provide valid results even when the sample size is small (Ifa and Guetat, 2018). We applied the PP and KPSS tests, and the Lee-Strazicich tests with one and two structural breaks to identify the order of integration of all our test variables.

To investigate the relationship between the energy price and COVID-19 cases, we created the following two log-linear models for crude oil and natural gas:

Model 1

$$\text{Ln(Oil price)} = c + \beta_1\ \text{COVID19} + \beta_2\ \text{Ln(gas price)} + \beta_3\ \text{LnDJUSAU} + e_t \qquad (1),$$

Model 2

$$\text{Ln(Gas price)} = c + \beta_1\ \text{COVID19} + \beta_2\ \text{Ln(WTI price)} + \beta_3\ \text{LnDWCLEC} + e_t \qquad (2),$$

where is either the U..S. and World total number of COVID-19 cases, DJUSAU is the Dow Jones U.S. Automobiles Index, DWCLEC is the Dow Jones U.S. Electricity Total Stock Market Index, and is the white noise error term. For the crude oil model, we tested the model for both cases for WTI and Brent crude oil prices. For the natural gas model, we investigated the model with the NYMEX Henry Hub futures price. The gas price and the DJUSAU in equation (1) and the WTI crude oil price and the DWCLEC in equation (2) are included in the models as fixed variables to capture the effects of factors other than the COVID-19 cases that could influence the oil and gas prices. In both Models 1 and 2, we tested the effects of the COVID-19 cases for the U.S. and global total numbers.

First, we estimated the simple ARDL, and second, we performed the ARDL bounds F-test for cointegration. Finally, we evaluated the conditional error correction ARDL models for the oil and gas price models. All models have been tested for the serial correlation test with the Breusch-Godfrey test and the parameter stability is tested with the CUSUM test.

The WTI and Brent crude oil prices are the daily USD per Barrel prices and the Henry Hub natural gas price is the daily USD per 1 million British thermal unit (MMBtu) price. All these daily prices are obtained from the Markets Insider site. The data for the U.S. daily COVID-19 case (COVID-U.S.) and the global daily COVID-19 case (COVID-World) are from the World Health Organization (WHO) and the European Centre for Disease Prevention and Control (ECDC). Finally, DJUSAU and the DWCLEC are quoted from the ADVFN website.

Results

To confirm the level of integration of the variables of our interest, we performed the PP, KPSS, and the Lee-Strazicich unit root tests. The stationarity tests presented in Table 1 indicate that all the variables

	WTI and COVID-US		WTI and COVID-world	
Variables	Coef	t-stat	Coef	t-stat
Intercept	0.525	1.311	-0.999 ***	-3.338
LnWTI(-1)	0.263 **	2.330	0.367 **	2.671
LnWTI(-2)	na		0.227 *	1.830
LnCOVID-US	-0.047 ***	-5.107	na	
LnCOVID-World	na		-0.030 ***	-2.856
Lngas	0.090	0.417	0.104	0.416
LnDJUSAU	0.436 ***	5.431	0.506 ***	4.610
	Brent and COVID-US		**Brent and COVID-world**	
	Coef	t-stat	Coef	t-stat
Intercept	0.759 *	1.974	-0.507 *	-1.823
LnBrent(-1)	0.408 ***	3.560	0.687 ***	7.468
LnCOVID-US	-0.041 ***	-4.506	na	
LnCOVID-World	na		-0.061	-1.132
LnCOVID-World(-1)	na		0.033	0.686
Lngas	-0.148	-0.753	-0.014	-0.062
LnDJUSAU	0.325 ***	4.327	0.367 ***	3.401
	Gas and COVID-US		**Gas and COVID-world**	
	Coef	t-stat	Coef	t-stat
Intercept	-0.820	-1.345	-0.588	-1.032
Lngas(-1)	0.773 ***	5.217	0.783 ***	5.016
Lngas(-2)	-0.227	-1.519	-0.231	-1.586
LnCOVID-US	0.013	0.911	na	
LnCOVID-US(-1)	0.015	0.799	na	
LnCOVID-US(-2)	-0.028 **	-2.103	na	
LnCOVID-World	na		-0.002	-0.509
LnCOVID-World(-1)	na		na	
LnWTI	0.031	0.588	0.021	0.581
LnDWCHLC	0.119	1.459	0.100	1.195

Table 2 ARDL estimations
*Note: *** and ** denote significance at 1% and 5% respectively.*

Model	F-stat
WTI vs COVID-US	16.21 ***
WTI vs COVID-World	8.60 ***
Brent vs COVID-US	10.12 ***
Brent vs COVID-World	4.69 **
Gas vs COVID-US	5.91 ***
Gas vs COVID-World	5.35 **

Table 3 Bounds F-test for cointegration
*Note: *** and ** denote significance at 1% and 5% respectively*

except the world total COVID-19 (COVID-World) cases are I(1). The Lee-Strazicich with one structural break and the PP test suggests that COVID-World is either I(1) or I(0). Hence, all our test variables satisfy the precondition of ARDL.

Table 2 depicts the results of the ARDL estimation. The optimal number of lag length of the ARDL models is determined with the AIC by setting the maximum lag length to four. The two models in the top of the table illustrate the results of the effects of the U.S. and world total COVID-19 cases on the WTI crude oil prices. It is discernible from the table that increased COVID-19 cases in the U.S. and World both had negative impacts on the WTI crude oil price. Similarly, the result of the first model in the middle of the table suggests that the U.S. COVID-19 cases negatively affected the Brent crude oil. Finally, the natural gas models in the bottom of the table indicate that both the U.S. and World COVID-19 cases did not have a statistically significant influence on the gas price.

These contrastive result between the crude oil and natural gas markets might be reflecting the difference in their use. Since crude oil is more used for automobile or jet fuels compared to natural gas, it could be that the decreased number of people using automobile and airplanes after the increase in the COVID-19 cases had some impacts on the crude oil prices.

Table 3 shows our results of the ARDL bounds test for cointegration. The results indicated that in all our models the F-statistics were higher than the upper-bound critical values at the 5% level. This indicates that both the crude oil and natural gas prices are cointegrated with the U.S. and World COVID-19 cases. Finally, Table 4 illustrates the results of the conditional error correction ARDL estimations. It is observable that the same distinctions on the effects of the COVID-19 cases on the prices hold between the crude oil and natural gas models. The COVID-19 cases have negative impacts in the crude oil models, but such effects are not apparent in the natural gas models.

	WTI and COVID-US		WTI and COVID-world	
Variables	Coef	t-stat	Coef	t-stat
Intercept	0.325	1.311	-0.999 ***	-3.338
LnWTI(-1)	-0.737 ***	-6.535	-0.405 ***	-4.377
D(LnWTI(-1))	na		-0.227 *	1.830
LnCOVID-US	-0.047 ***	-5.107	na	
LnCOVID-World	na		-0.030 ***	-2.856
Lngas	0.090	0.417	0.104	0.416
LnDJUSAU	0.436 ***	5.431	0.506 ***	4.610
	Brent and COVID-US		**Brent and COVID-world**	
	Coef	t-stat	Coef	t-stat
Intercept	0.759 *	1.974	-0.507 *	-1.823
LnBrent(-1)	-0.392 ***	-5.160	-0.313 ***	-3.408
LnCOVID-US	-0.041 ***	-4.506	na	
LnCOVID-World(-1)	na		-0.028 **	-2.588
D(LnCOVID-World)	na		-0.061	-1.132
Lngas	-0.148	-0.753	-0.014	-0.062
LnDJUSAU	0.325 ***	4.327	0.367 ***	3.401
	Gas and COVID-US		**Gas and COVID-world**	
	Coef	t-stat	Coef	t-stat
Intercept	-0.820	-1.345	-0.588	-1.032
Lngas(-1)	-0.454 ***	-3.719	-0.469 ***	-3.855
LnCOVID-US(-1)	0.000	-0.008	na	
D(Lngas(-1))	0.227	1.519	0.231	1.586
D(LnCOVID-US)	0.013	0.911	na	
D(LnCOVID-US(-1))	0.028 **	2.103	na	
LnCOVID-World	na		-0.002	-0.509
LnCOVID-World(-1)	na		na	
LnWTI	0.031	0.588	0.021	0.581
LnDWCELC	0.12	1.46	0.10	1.20

Table 4 Conditional error correction ARDL estimations
*Note: ***, **, and * denote significance at 1%, 5%, and 10% respectively.*

The Breusch-Godfrey test performed to identify the serial correlation in the model suggested that except for the WTI crude oil model with the world COVID-19 cases, the models did not contain the serial correlation issue. The CUSUM diagnostic test for parameter stability confirmed that all our estimated coefficients satisfy the stability condition at the 5% significance level.

Conclusions

COVID-19 will transform energy markets, and it already seems to be causing effects on the oil market. Our study proves that increased COVID-19 cases in the U.S. and world both had negative impacts not only on the WTI but also on the Brent crude oil price. Finally, our natural gas models indicated that both the U.S. and World COVID-19 cases did not have a statistically significant influence on the gas price.

Possible explanations of this relationship include a number of reasons. Firstly, when it comes to the U.S., due to the beginning of the covid-19 outbreak in March 2020, precise influence over gas prices might have been not recognized at the moment this study was prepared. Secondly, world natural gas prices have already been low enough due to market fundamentals. Mild winter, huge expansion of world LNG capacity and increased storage levels pushed prices to its record low tracks. In January 2020, the Henry Hub spot price remained below $2 per mmbtu reflecting its worst levels of $1.6 per mmbtu in 1995 (Dewar, Vazquez and Bori, 2020). Another possible explanation for the lack of COVID-19 influence over gas prices might be the fact that natural gas prices react differently in various time horizons. As Brown and Yücel (2007) prove natural gas prices are anchored in a long-term relationship with crude oil prices, but the short-run dynamics can result in considerable variation in relative natural gas and crude oil prices. It might be that natural gas prices within our model (which depicts short term relationship) did not have enough "time" to adjust to market changes. It is probable, that COVID-19 footprint over the gas prices will be revealed in the coming months as demand for LNG in Europe will further decrease and will lead to oversupply of gas.

But there are also forecasts (Bakx, 2020) that natural gas will take advantage of plummeting oil prices as mainly in the U.S., since in the U.S., most of its natural gas is produced from oil wells. Contrary to gas prices, the COVID-19 influence over the oil market was visible in the last months. People stopped travelling using planes as Pew Research Center (2020) claims 93% of the world's population (7 bln people) as of March 31, 2020 lived in countries with travel restrictions and 39% (3 billion people) lived in countries with borders completely closed. Social distancing in many countries changed work-life patterns leaving cars idle and decreasing frequency of public transport and thus decreasing demand for refined crude oil products. In summary, the energy sector will change due to COVID-19, apart from short term shock consequences, and there will be some long-term changes in the demand patterns (UAEE, 2020). That will not only affect hydrocarbon markets, but also renewables, as global supply chains have already been disrupted.

Our study as any other research has its limitations. Firstly, due to sample size and scope, our results provide information on aggregated world and disaggregated U.S. level. We have not carried out the analysis for separate European countries, such as Italy, Spain or even UK (in the first days of April), that at the time of article writing have been heavily infected with coronavirus. The situation has been changing within days during article preparation. Secondly, since we have not included in our research any variable reflecting Russia-OPEC+ dispute as we believe that this phenomenon might have been captured by fixed variables other than COVID-19 cases. In ARDL oil price model these were: gas price and the DJUSAU and the respective gas price model: the WTI crude oil price and the DWCLEC. Allowing for time horizon, geographical scope, dispute specific variable extension, might be the next research step.

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Impact of Coronavirus on Distributed Energy Generation with the Application of Demand-Side Management

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The Coronavirus pandemic will change the way we live and perceive the world around us and thus, will undoubtedly also affect the way we use energy. The energy sector is already feeling the effects of the coronavirus and these are not expected to go away anytime soon. The global lockdowns changed radically the energy demand patterns due to shut downs of industries, business and schools and necessitating home-office. This new pattern makes it difficult for grid operators to predict energy demand. Additionally, in most countries with strict confinement measures energy demand has dropped dramatically. For instance, electricity demand dropped by 18% in Italy[1] and by 10% in Spain[2], compared to the demand before the quarantine measures. At the same time, many of these countries/regions like Spain and California rely heavily on renewable energies. This gives us a good indication of how a future network with higher renewable energy penetration could work. The high intermittency of the renewables along with the more unpredictable energy demand patterns, and the shut down of industries which normally apply real time demand management also highlight the need for more network flexibility. The idea of demand side management (DSM) deals with these issues as it tries to balance supply shortage, grid inefficiencies and overloads. Distributed Energy Resources (DERs) feed electricity into the grid while the DSM removes the extra demand out of the grid.

The concepts of DSM via DERs has been discussed intensively the past years, but there are still limited applications and various obstacles. However, one could speculate that the coronavirus outbreak and the new circumstances will push for DSM application and energy decentralization in the longer term for the reasons explained below.

Digitalization

During coronavirus pandemia and due to the lockdowns we observed more reliance on digital technology for everyday tasks like video conferences, online teaching environments and digital workoust. All these can lead to a change in mindset, pushing towards the direction of the massive digitalization of our societies in the upcoming years. Although energy has traditionally been a sector that has resisted digitalization sticking with the traditional centralized model of energy flow from the producer to the consumer, one could expect that post coronavirus the trend will be reversed.

The rise of artificial intelligence (AI) can make possible real-time predictions of generation and demand. This can change the way we produce and consume energy making the households important players in the energy market alternating from consumers to producers. During times of crises and uncertainty people are concerned about things they cannot control and electrical reliability is currently one of those. With the use of distributed energy resources (DERs) with real time DSM the households will increase their resilience as they will be able to directly regulate their energy production and consumption through internet applications, reducing their dependence on utilities and securing their autonomy for themselves and their communities in future crises.

Indeed already there is an increased worry regarding the security of electricity supply. Although many companies assure that they are well prepared to face the pandemic[3,4] the uncertainty highlights the fact that in times of uncertainty

However, this transition will require time. In the near future, right after the outbreak, there will be few new renewable energy projects, due to the disruptions in the supply chain and lack of liquidity. Already manufacturers forewarn on delays in scheduled projects.[5]

Additionally, the utilities will face severe problems due to payment delays. Already in many countries, utilities are offering relieves for vulnerable consumers who are unable to pay. This money will have to be recovered after the outbreak and thus, consumers may face considerably higher utility bills. This can push consumers to consider cheaper long term alternatives, including generating their own electricity. Short term however, individual consumers will have less available finance to invest on renewable energies and smart meters in their households, delaying the transition to a decentralized system with integration of flexible demand.

One may also suspect a reduction in the demand response as this is often integrated with the industrial operation which is slowed down. In countries like Spain in which there was the provision to start the operation of the demand management market this June there will be significant delays.

In the longer term, however, and as digitalization advances under the new reality, the idea of demand-side management, with the integration of distributed energy will become increasingly predominant. These can vary from small, stand-alone electricity generators that allow for energy stockpiles, to more complex systems integrated with the grid.

This will change not only the way we talk about energy, but also the way our communities are organized. Various networks will emerge among prosumers, allowing the function of a peer-to-peer energy market in neighborhoods or in apartment blocks. The adoption of DERs will allow for an optimization of the energy demand and more efficiency that can eventually reduce consumption. At the same time, it will make energy management and grid operation less manual allowing for online control and increasing autonomy. Electricity stockpile through batteries will be possible. Energy utilities will also invest in DERs allowing them to operate cleaner and more reliable systems, using more automation that will reduce the risks in a future pandemic scenario.

Of course this transition to decentralization through DSM will raise big questions especially regarding the role of utilities, the safety of the system against potential cyberattacks and the use of personal data.

Today, the coronavirus outbreak not only highlights the importance of a reliable electricity system, but also paves the way for big changes in line with the digitalization advances, the rise of clean technologies, and the democratic arrangements that will call for new community arrangements.Despite the initial delays on the operation of demand side management, long term we can expect that the digitalization and the need for control over energy will push for distributed energy sources with the use of distributed energy sources in order to ensure security, reliability, and efficiency of the electricity supply in the post coronavirus market environment.

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The Impact of the COVID-19 Crisis on Energy Prices in Comparison to the 2008 Financial Crisis

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The authors' contributions to this analysis are as follows: conceptualization, **Hauser**; introduction, **Gutiérrez López;** methodology, **Schönheit, Hauser**; analysis oil, **Gutiérrez López, Schreiber**; analysis natural gas, **Hauser;** analysis coal, **Scharf**; analysis carbon prices, **Anke**; analysis electricity, **Scharf**; conclusion, **Hauser, Anke, Gutiérrez López, Möst, Scharf, Schönheit, Schreiber**; editing of the manuscript, **Schönheit, Gutiérrez López;** visualization, **Anke, Scharf, Hauser**; supervision, **Hauser, Möst.**

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Introduction and Motivation

The COVID-19 pandemic has forced governments around the world to impose strict social-distancing measures among the population to ease the burden on health care systems and slow down the spread of the virus. European countries have seen an abrupt shutdown of their economies; except for basic necessities all other sectors of the economy have been affected by an unprecedented demand contraction and a declined supply of goods. The energy sector is no exemption, historical consumption profiles have changed as people's and industries' routines have been drastically shuffled, transportation is kept to minimum levels and cycling and walking have risen in importance as a result of curfews.

This contribution analyzes the impact of COVID-19 on price developments of the main five energy commodities, oil and coal globally, gas and CO2 certificates in Europe as well as electricity in Germany, with that observed during the world financial crisis of 2008. In particular, we address the following questions:

- What is the behavior of electricity, oil, gas, coal and carbon prices during COVID-19?
- Are there any similarities (or differences) in price behavior with the same period in 2018, 2019 and 2008?
- Besides the COVID-19 crisis, are there additional drivers for commodity prices at the moment?

The energy markets have never experienced a crisis on the scale of COVID-19, and comparisons with other crises may seem at first misplaced; however, the financial crisis—albeit different in causes and progression—is the worst latest reference the sector has and it is insightful to understand where we stand and what lessons could be drawn for current market developments.

The following sections address the methodology, criteria and assumptions for the selected comparison time frames, the general and crisis-specific drivers for each commodity, and the final discussion and conclusions, highlighting reasons behind price movements in both crises.

Methodology

To depict the current price trends of the chosen energy commodities and compare them with the 2008-crisis, price time series in 2020 up to April 9 are analyzed. All months of 2020 were characterized by news regarding COVID-19 with various degrees of severity. Hence, three points in time are selected as "events" which likely affected markets (cf. also The Berlin Spectator, 2020):

- Monday, 27.01.2020: First European cases in France on January 25 and the first German case on January 27 (ZDF, 2020).
- Monday, 24.02.2020: Germany's Federal Minister of Health, Jens Spahn, states that COVID-19, as an epidemic, has reached Europe and its spread in Germany is anticipated (Federal Ministry of Health, 2020). EURO STOXX 50 and DAX started plummeting the Friday before and strongly continued on this Monday (WSJ, 2020).
- Monday, 23.03.2020: Schools and daycares closed in all German states and ban for social meetings is imposed (Merkur, 2020; Federal Ministry of Health, 2020).

Although some impacts have been observed before, March 23, 2020 is the appointed date (AD) for the setting in of the COVID-19 crisis within this analysis. The trends in commodities before and after this date will be juxtaposed with the trends before and after the AD of 2008's financial crisis, which is set to September 15, corresponding to the announcement of Lehman Brothers' bankruptcy. Hence, March 23, 2020 and September 15, 2008 will serve as ADs, whose values are the basis, from which percentage deviations will be presented.[1] The trends from 2018 and 2019 are also shown for a comparison of recent developments in commodities. March 26, 2018 and March 25, 2019 serve as ADs, so Mondays are used in all years.

Impact of the COVID-19 pandemic in energy commodities with focus on Germany

Overview on energy commodity price curves

The current COVID-19 pandemic affects energy commodities in different ways. Figure 1 shows normalized price curves for electricity, coal, carbon, gas and oil in relation to the appointed date of each year. Detailed analyses of each commodity as well as discussions on causes and effects follow in the corresponding sections below.

Oil

The COVID-19 pandemic is an unprecedented shock to the global oil industry: the sharp drop in oil demand, mostly driven by a worldwide standstill transport sector, has collapsed oil prices; an oversupply—due to lifted restrictions for OPEC+ producers and a price war between Russia and Saudi Arabia—is, in turn, seizing up available storage capacities and lowering price even further.

Day-ahead prices of the domestic West Texas Intermediate (WTI) and international Brent crude oil are strongly fluctuating: in March/April 2020 prices reached absolute levels lower than those seen during the financial crisis in 2008, although the absolute price delta remains below 2008's. The price decline during the financial crisis started at approx. 145 USD/bbl (Jul 08) and turned down to 30 USD/bbl (Dec 08), which is a 80% fall and a delta of 115 USD/bbl; the price plummet in 2020—started even before COVID-19 due to the oil price war—went from 63 USD/bbl (WTI) and 72 USD/bbl (Brent) in January to its lowest level in history, 17 USD/bbl (WTI, 26/03/20) and 11 USD/bbl (Brent, 01/04/20), which is a 73% (WTI) and 84% (Brent) decline and a price delta of 46 USD/bbl (WTI) and 61 USD/bbl (Brent), respectively.

The standard deviation of the price fluctuations in both crises seems to be similar for the given timeframe: 14-16 USD/bbl (COVID-19) and 16-18 USD/bbl (financial crisis). The International Energy Agency forecasts a price stabilization for the end of the second quarter of 2020, (IEA 2020). This would follow a path, similar to the financial crisis, where the lowest oil price level was reached three months (Dec 08) after the starting point of the crisis (Sept 08).Figure 1: Price curves in oil, gas, coal, carbon and electricity markets of calendar week (CW) 3 to CW 22 in 2018, 2019 and 2020 compared with the financial crisis in 2008 (Source: Thomson Reuters Datastream (2020), EEA (2012), ENTSO-E (2020), OPSD (2019)).

Fuel efficiency measures had already lowered oil demand from the transport sector—especially road and maritime—, but the major shock comes from the sharp cut in passenger mobility especially in flight and road modes. As an example, as of March 29th, mobility in transit stations in Germany had declined around 70% compared to the baseline (Google, 2020) and the demand shock grows as countries enforce more lock down measures. In contrast, during the financial crisis, passenger mobility—driven by the disposable income—was only slightly affected, decreased 5% worldwide (Moschovou & Tyrinopoulos, 2018), but international trade was severely reduced and the freight sector of major exporting countries saw declines of over 20% (Rothengatter, 2011).

Natural gas

For the past years, gas prices have continuously decreased due to milder winters, increased shares of LNG imports—mainly driven by US gas—and consequent greater volumes of stored gas. Figure 1 shows the gas prices in the NetConnect Germany market area. Due to price convergence, this series can be seen as a proxy for European gas prices. This declining price trend also holds for January and February of 2020—just before the COVID-19 crisis hit Europe—as the gas price at the AD was on a much lower level (8.25 EUR/MWhth) compared to 2019 (15.20 EUR/MWhth) and 2018 (18.02 EUR/MWhth).

However, from the week before the AD to the following, the price dropped 20% compared with a decline of 6% in 2019 and 2% in 2018 over the same weeks. This would mean that the COVID-19 crisis led to a larger relative decrease in the seasonal price of natural gas compared with the two previous years without a crisis. In contrast, during the Lehman Brothers bankruptcy in 2008 prices remained stable, possibly due to a stronger interlinkage between oil and gas prices in long-term gas supply contracts; while in 2020, gas prices are increasingly affected by liquid spot markets and gas-to-gas trading.

When the COVID-19 crisis hit, there was no sudden gas price collapse within a couple of days but the underlying economic crisis is affecting gas price drivers. Hauser et al. (2016) discuss gas price determinants in detail.

On the supply side, increased competition within gas markets has already led to an overall price decline and fuller storages: by the end of March 2020, German suppliers were storing 164 TWhth (72% of total capacity) compared to 122 TWhth in 2019 and 33 TWhth in 2018. As storage levels depend on the coldness of the previous winter, a COVID-19-induced demand contraction over the coming months will further pressure gas suppliers.

Current gas price movements are driven by remaining high supply capacities and decreasing demand. Demand for gas in Germany comes from the heating, power, and industry sector and they are affected by the COVID-19 crisis in varying degrees. Due to previous mild winters, the already low gas demand from the heating sector is not expected to further change with the crisis. The gas demand from the power sector relies not only on the electricity demand, but also on the share of renewable energy sources (RES), which is also discussed in the electricity section. Finally, as gas is used in many industries, which have a share of approx. 30% in total gas demand in Germany (e.g. chemical processing and metal industry) and are likely affected by the crisis, a longer-term reduction of industrial demand is also probable.

Coal

During the COVID-19 crisis, a clear decline in coal prices cannot be identified. As Figure 1 shows, prices

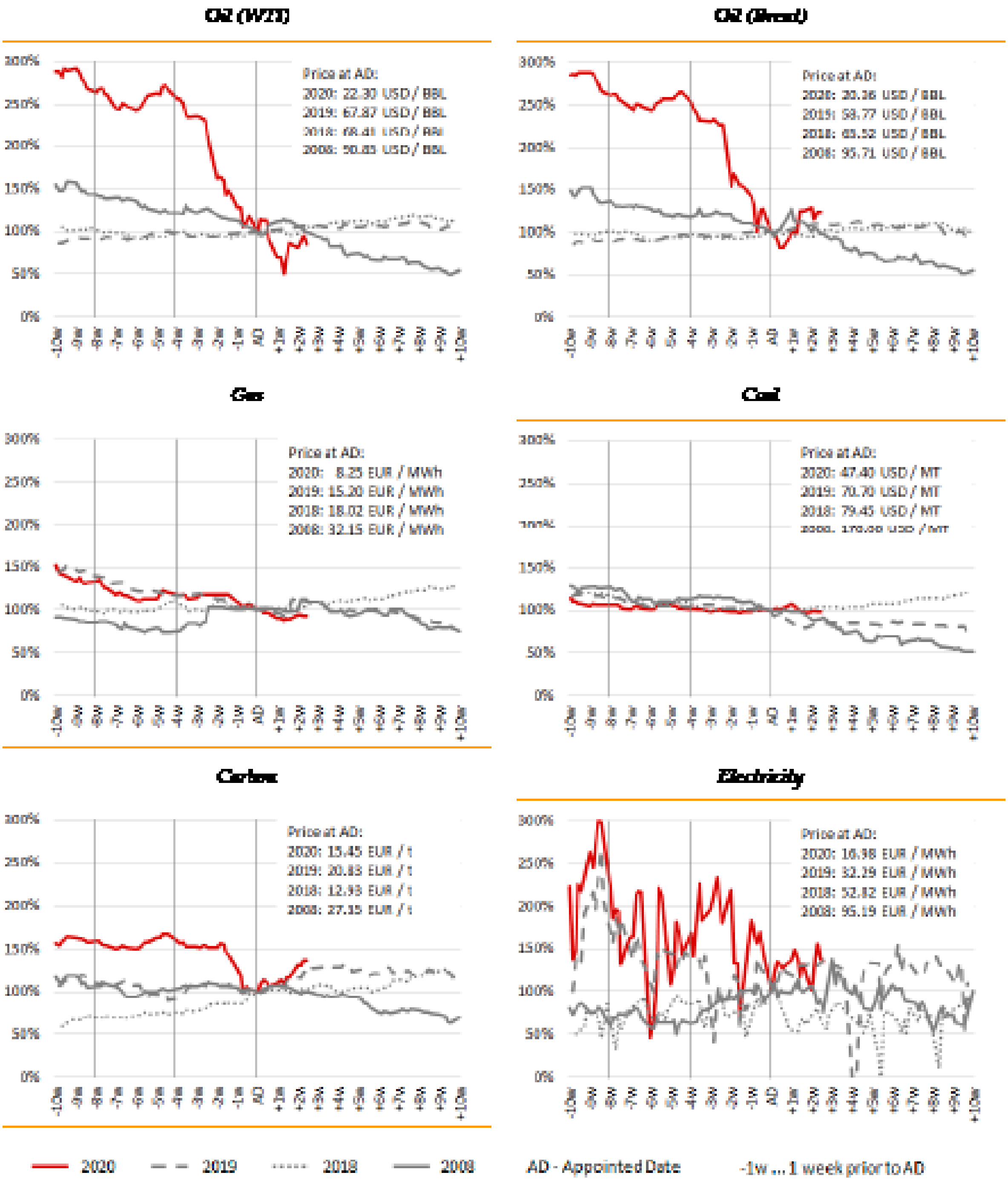

Figure 1: Price curves in oil, gas, coal, carbon and electricity markets of calendar week (CW) 3 to CW 22 in 2018, 2019 and 2020 compared with the financial crisis in 2008
(Source: Thomson Reuters Datastream (2020), EEA (2012), ENTSO-E (2020), OPSD (2019)).

were already comparably low before New Year 2020. There was a clear drop at the end of March 2019 from price levels that were continuously higher than 70 USD/t to prices of about 60 USD/t. Since then, an overall declining trend continued, so that prices were at about 50 USD/t at the end of March 2020. It can be concluded that the effect of the COVID-19 crisis on coal prices is comparably low and that influencing factors that put coal prices under pressure already existed before the crisis (e.g. falling gas prices, prices of ETS certificates) and are still the main drivers (IEA, 2019).

During the financial crisis, by contrast, a clear effect of global hard coal demand on prices can be observed. Before this crisis, coal producing companies increased their investments significantly. When global hard coal demand dropped sharply due to the crisis, companies addressed the drastic decline in cash flow with a reduction of prices. There was an overall, steep decrease in coal price to 2006 levels, starting in July 2008 until the beginning of 2009 (IEA, 2009).

Carbon

Like fuel prices, prices of European Union Allowances (EUA) decreased due to the COVID-19 crisis, from 25 to 17 EUR/t (-30%). This direct and sharp market reaction was not observed in the financial crisis of 2008. In 2009, market reacted much slower, with first price declines six weeks after Lehmann Brothers' bankruptcy, although ultimately the price decreased by up to 60%. The financial crisis and the related lower industry production contributed to low carbon prices for almost a decade (Bel & Joseph 2015). These low prices allowed policy makers to tighten the regulation of EU ETS (Emissions Trading System) and hence to reduce its cap, e.g. with the instruments of back loading, market stability reserve (MSR) as well as a higher reduction factor in phase 4. However, all this was possible because the EU ETS was oversupplied and it lost its capability to provide sufficient price signals for the mitigation of carbon emissions.

Looking at today's EU ETS, a reduction in carbon emissions is observed due to COVID-19. Currently, it is unclear if this short-term reduction will lead to an overall long-term reduction in emissions in the EU ETS. This depends on the fundamental situation of the EU ETS that can either stay scarce or the market turns long and is oversupplied with EUAs. In the latter case, the MSR will reduce the number of available EUAs, which allows policy makers to tighten the regulation again. However, it is highly questionable if this is a focus of policy makers due to the upcoming economic crisis. Otherwise, if the market remains scarce, short-term industry production declines and emission reduction will only decrease the EUA price, which can already be observed. But overall emissions in the ETS sector will not decrease since the European emission cap is constant. Therefore, emissions in the ETS sector will occur later or in a different area. This so-called "waterbed effect" is widely discussed in association with the coal phase-out (Rosendahl 2019).

Electricity[2]

Figure 1 suggests that day-ahead electricity prices have fallen since the start of lock-down measures in Germany (CW 13) and are also lower compared with the same time frame in reference years (2018 and 2019). While in the CW 13 of 2020, average price was 20.93 EUR/MWhel, on the same days of this calendar week, average price was 38.33 EUR/MWhel in 2019 and 40.52 EUR/MWhel in 2018. In contrast, the Lehman Brothers' bankruptcy does not exhibit a clear impact on day-ahead prices.

The current effect on prices is unambiguous when comparing the first two weeks of the lock-down with similar weeks in terms of aggregated weekly generation fuel type in 2020: comparable weeks 13 and 6 show a difference of 12.22 EUR/MWhel—absolute values in week 6 are higher only for five of the 120 hours in the time-frame; weeks 14 and 12 exhibit 22.97 and 23.92 EUR/MWhel, respectively, which is a minor difference. Possibly the crisis had an impact in week 12 already, though prices in week 12 exceed week 14 for 32 hours only.

Three main factors influenced these price developments during the COVID-19 crisis: lower power demand—due to reduced industrial production and activities in the service sector—, lower prices of energy carriers and emission certificates, and higher feed-in from variable renewable generation (vRES).

1. Power demand. During the first two weeks of lock-down, demand was 420 GWhel lower than in the same weeks of 2019 and 161 GWhel lower in the same weeks of 2018; the latter gap is not as large because Good Friday and Easter Monday in the considered time span of that year lowered demand. Likewise, comparing the 15th week, demand dropped 1,090 GWhel (2019) and 903 GWhel (2018). Such a large decrease may not be solely explained by the public holiday on the 10th of April but may also respond to the generalized demand contraction triggered by the crisis.

2. Prices of energy carriers and ETS certificates. As discussed above, prices of gas and ETS certificates are following a sharper declining trend since the beginning of the crisis. Figure 2 shows decreasing variable unit costs for gas plants and slightly increasing ones for coal plants, suggesting that combined cycle gas turbines are progressively undercutting marginal costs of hard coal and lignite.

3. Renewables *feed-in (vRES).* During the first three weeks of the lock-down, low power demand has also faced a higher vRES feed-in (7.9 TWh_{el}) compared with the same time frame in 2019 (6.0 TWh_{el}) and 2018 (7.6 TWh_{el}). This higher feed-in, although independent from the COVID-19 crisis, has put downward pressure on power prices and production from fossil plants.

With respect to the two previous weeks, power demand in week 13 and week 14 decreased by 6.9% in Germany, 9.2% in France, 10.3% in the United Kingdom, 10.5% in Spain and 17.1% in Italy. Italy and Spain have shut-down all non-essential factories and had a more stringent curfew, while some (more) industries in Germany remained open, which could explain its comparatively small drop in power demand in Germany.

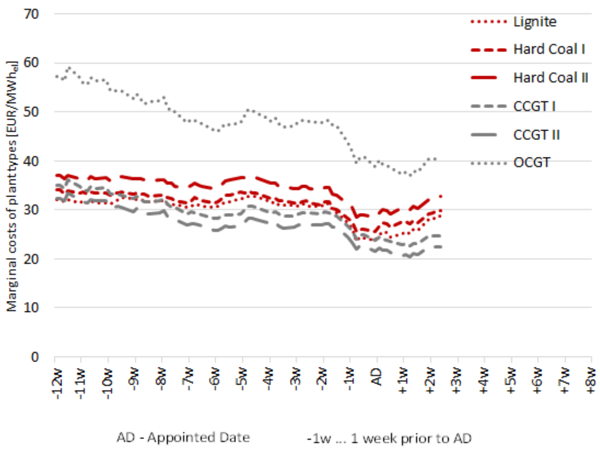

Figure 2: Variable item costs for different unit types. Properties of Lignite, OCGT, Hard Coal I and CCGT I are derived from Panos & Konstantin (2017, p. 154), and roman-II-plants are derived from JRC (2014). Fuel and carbon prices are from Datastream (2020). Own illustration.

Conclusion

The COVID-19 pandemic's impact on energy commodities is largely heterogeneous. The effect of COVID-19 on coal prices can be deemed indirect at most. The observed decline in European gas prices is a general trend due to mild winters, filled storages and increasing competition of pipeline gas and LNG. The COVID-19 crisis may affect fundamental drivers in the form of a decrease in gas demand in the power and industry sector due to a general decline of economic growth. Currently, significantly lower CO2 emissions are observed in the transport and industry sector. It is questionable whether a long-term effect for emissions covered by the emission trading system can be observed, especially if the overall carbon emission cap (EU ETS) remains constant. Long-term effects in the emission trading system will depend on stabilization mechanisms and outcomes of the Green Deal. The oil market is affected to a great degree as prices have reached historically low levels driven by both, a supply shock from the Saudi-Russian price war as well as a demand shock from the COVID-19 pandemic. The impact might be temporary, but long-term challenges foresee a highly unstable global financial situation.

In general, the COVID-19 shut-down results in a lower power demand, leading to an overall expected reduction in power output of conventional units. Shifts in the merit order of power plants in Germany can already be observed due to a change in the coal-to-gas price ratio. Hard coal is pushed out of the market, due to low gas prices, and lignite production is reduced to lower levels, an effect not compensated by low carbon prices. When determining the merit order with commodity prices from March 2, 2020, 5 GW of highly efficient CCGTs precede lignite in the merit order. This amount doubles when using prices from March 31, 2020. However, the weeks past the COVID-19 measures are also characterized by high amounts of renewable energy feed-in, which impedes parsing the effect of COVID-19 on electricity prices.

This analysis is a snapshot of short-term trends in energy commodity prices in 2020 and attests to the complexity of factors affecting energy markets. General trends and conditions, which exist independent of COVID-19, determine prices, but the pandemic-based demand shock further affects the commodities. An observable "COVID-19 energy price effect" is observed for all considered commodities with exception of coal. However, the COVID-19 crisis is still in its infancy and the long-run effects depend on the further developments and on the occurrence and severity of a persistent recession. Low prices for conventional energy sources in combination with a constant carbon cap (and consequent lower emission allowance prices) result in a weaker business case for renewable energies and will most likely make the clean energy transition more difficult.

Footnotes

[1]Some commodity prices show seasonal patterns. Consequently, the selected appointed dates of the two crises (spring vs autumn) also have an impact on price trends, but data is not adjusted by seasonal filters in this analysis.

[2] Values are taken from ENTSO-E (2020), unless otherwise indicated. It is assumed that COVID-19 predominantly affects business days' activities

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Electricity Demand Drops Down Due to COVID 19 Virus: Opportunities for Long-term Energy Storage in a Highly Renewable Electricity System

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With the outbreak of novel coronavirus (COVID-19), economic activities have been slowed down across the world. In the power sector, the most profound impact is the dramatic fall in electricity demand in many countries. For instance, China's electricity demand for the industry is estimated to decline by 73 billion kWh in 2020 [1], roughly the same as the annual electricity consumption in Austria. Other analyses have also shown an apparent decrease in electricity demand in Italy, Spain and France [2, 3]. The fast decline in demand has pushed down the electricity price in the wholesale market to multi-year lows and has led to large-scale curtailments of variable renewable energy (VRE). Recently, the combined systemwide solar and wind curtailments in California have spiked over 13,000 MW [4].

Due to political goals and decreasing costs for wind and solar, the share of VRE is increasing rapidly in the electricity system. A highly renewable electricity system is less capable of load-following due to the intermittency of VRE as compared with the conventional electricity system based on dispatchable power plants [5]. Therefore, renewable energy is curtailed to keep the real-time balance between electricity load and generation in the power system, and the curtailment is further enhanced with the outbreak of the coronavirus. Significant curtailment of renewable energy is not desirable, as cost-free and emission-free energy has to be wasted. In addition, the effective capacity factor for renewable power is reduced due to curtailment. How to utilize curtailed energy remains a challenge in the electricity system. One potential solution to this question is long-term energy storage.

Plenty of studies [6-9] in literature have investigated the role of energy storage in dealing with electricity curtailment, and the main functions of storage can be summarized as: (1). Temporally shifting electricity generation from congested periods; (2) Providing flexibilities back to the grids when there is little output from VRE power plants. Energy storage serves as an option to store renewable energy during periods of surplus generation and discharging during periods of limited output. A large amount of storage is adopted for studies on long-term investment planning of the future renewable electricity system. However, the invested storage is dominated by short-term battery storage to deal with the daily mismatch of renewable supply and electricity demand. Long-term storage, on the other hand, seems to be less attractive. This is mainly because many studies limit the system boundary to electricity system only without sector coupling, which neglects the potential contributions from long-term storage to other sectors, such as heating, transportation and industry. Studies considering sector coupling usually linearly scale up the historical demand profile to a new value for the future electricity demand. Despite the fact that the annual electricity consumption change is considered, the intertemporal pattern of the demand profile is assumed to remain the same. Therefore, the electricity consumption patterns for other sectors are not well represented, which leads to an underestimation of the peak demand and flexibility requirements for the electricity system. Besides, the curtailment of renewables is modest both in volume and temporal duration. Last but not least, the investment cost is high for some infrastructures such as hydrogen electrolyzer, the key equipment to produce green hydrogen from water.

With the on-going quarantine policy, shutting down of industrial production and offices, we are facing an unusual "disruption" in the electricity system: continuous low electricity demand for a long period. So far, it is still not clear how long this epidemic will last. One implication out of this contingency for the planning of future electricity system is to take into account the plausible scenarios with long-term low electricity consumption. The continuous electricity curtailment in such scenarios would make the investment in long-term storage appealing. In addition, the cost of long-term energy storage technology has been decreasing over time. One ample example relates to the electrolyzer, the cost for which has fallen by 40% in the last five years [10]. The future decrease in cost can be expected with more deployment and continuous policy support.

In reality, to achieve the ambitious goals set by the Paris Agreement, the power sector is expected to mitigate nearly all its CO_2 emissions and meanwhile contribute to carbon reduction in the transport and heating sectors. The energy demand for transportation has a typical diurnal variation. In stark contrast, energy demand for heating has an evident seasonal variation, with most of the consumption concentrated in winter. Considering the intensive diffusion of both electric vehicles and electric heating, the winter peak demand will grow significantly. Regarding such a large seasonal variation in electricity demand, long-term storage technologies such as thermal energy storage, power to hydrogen are good options to tackle the seasonal mismatch between electricity demand and VRE generation. For example, thermal energy stored in summer and autumn with favorable solar irradiance can be used to deal with the high heat demand in winter when there is little output from wind and solar. This will largely decrease the investment in other back-up capacities. By comparison, green hydrogen can not only provide flexibility back to the grids but also help to decarbonize some hard-to-abate sectors such as the steel industry.

The coronavirus has spread over 210 countries and territories and resulted in more than 140,000 deaths. This is a worldwide tragedy for the current generation. While we are mourning the great losses, opportunities are approaching us. Long-term energy storage is a potential option to be adopted in such opportunities to shift renewable energy generation over time to guarantee the security of electricity supply and mitigate CO_2 emission at the same time. Nevertheless, policy is essential for long-term energy storage to gain use. This relates to policies to foster sector coupling; policy supports for scaling up hydrogen production and investment in supply networks; Besides, emission policies are important to motivate the shift from energy production with fossil fuels to long-term energy storage.

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The Impacts of COVID-19 on China's Domestic Natural Gas Market

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Introduction

This paper examines to what extent the new pandemic named COVID-19 by WHO, has impacted the domestic natural gas market in China. We provide a sectoral decomposition of the effects and discuss their potential short and long-run impacts. There is an important literature on the determinants of gas consumption in China and the future evolution of the gas market and gas consumption (Wang and Lin, 2014; Zeng and Li, 2016; Wang and Lin, 2017; Jiang et al., 2020). In addition, there is a stream of work on the potential economic impacts of COVID-19 (Qiu et al. 2020). However, to our knowledge, none of these works analyzes the specific impacts of COVID-19 on the Chinese natural gas market.

Natural gas is a more efficient and cleaner fossil fuel energy compared to coal and petroleum. The need to mitigate climate change by reducing global CO2 emissions has led China to increase the share of gas in its energy mix to foster its energy transition (Li et al., 2011). In 1997, China's natural gas consumption was 19.8 billion cubic meters (bcm) which was 1.8% of world consumption. In 2015, this rose to 194.7 bcm (5.9% of world consumption) (Jinag et al., 2020) and peaked at 375.473 bcm in 2019 (Zang and Yang, 2015). The annual rate of growth of natural gas consumption in China is 13.5% (Zang and Yang, 2015).

Given the specificities of natural gas, to better adjust production and importation we need to forecast the evolution of consumption. There are several studies such as Wang and Lin (2014), Wu et al. (2015), Zeng and Li (2016) and Jiang et al. (2020) which use various datasets and estimation methods[1], and forecast increased consumption; however, none include risk of a pandemic.

COVID-19 has affected the consumption, production, storage and price of gas in China and these effects will remain in place in the immediate future due to uncertainty about potential new waves of the disease and its spread worldwide. COVID-19 is causing the most significant depression in modern history. Understanding the impact of COVID-19 on China's domestic gas market should be valuable for other countries and allow better management in future similar crises.

Our paper provides four main findings. First, growth in demand for (but not the quantity) natural gas in China experienced a significant drop during Q1-2020 due to COVID-19 and Chinese policy interventions. Second, the decreased demand for gas for industrial activity was almost completely offset by increased household demand for heating and cooking. Third, the downward trend in the price of LNG for non-residents strengthened but there was no change in the price paid by residents signaling incomplete deregulation in the downstream market. Fourth, artificially low domestic prices discouraged growth in domestic production exacerbated further by the low international prices caused by the pandemic.

The paper is organized as follows. Section 2 describes the gas market in China before COVID-19; section 3 discusses and decomposes the effects of COVID-19 on the gas market; section 4 summarizes the findings and concludes.

Spread of COVID-19 in China

In December 2019, a cluster of patients suffering from a new strain of pneumonia was identified in Wuhan, capital of China's Hubei Province. On January 7, 2020, the pneumonia was diagnosed as being caused by a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which the World Health Organization termed COVID-19.

On January 11, China reported its first death from COVID-19. Meanwhile, cases occurred in other Chinese cities and other countries and there were fears of a global outbreak (Wu et al., 2020). On January 20 there were 282 confirmed cases of COVID-19 in China, Thailand, Japan and the Republic of Korea. On January 27, there were 2,798 confirmed cases were in 12 countries (WHO, 2020a).

To slow the spread of COVID-19, on January 23 China put Wuhan under lockdown and imposed aggressive measures including suspension of flights and trains, cancelation of subway transport and buses, and a ban on all mass gatherings. People were told to work from home, schools and shops (except food and medicine retailers) were closed. In some areas, residents were not allowed to visit shops or order deliveries. Similar though softer measures were adopted later by many other Chinese cities and everyone was encouraged to stay at home to stay safe and help prevent the spread of COVID-19. As the number of cases rose, the health sector in China was strengthened, new hospitals were built and reserve beds were used. On February 20, China had 75,465 reported cases of COVID-19 (WHO, 2020b).

It seems the lockdown was effective. On February 27, there were 36,117 reported cases of recovery from COVID-19 in China (WHO, 2020c). The number of new cases fell and the number of COVID-19 survivors continued to increase. However, the disease spread quickly to many other countries and on March 11 was declared a pandemic by WHO. On April 8, China lifted the 76-day lockdown in Wuhan. However, due to fears of a second wave of infections, some restrictions remained in place. On April 16, China reported 1,107 active cases of COVID-19, 77,892 patients who had recovered and 3,342 deaths from the disease (Worldometer, 2020), while across the world there were 2,094,884 reported cases and 135,569 deaths in 210

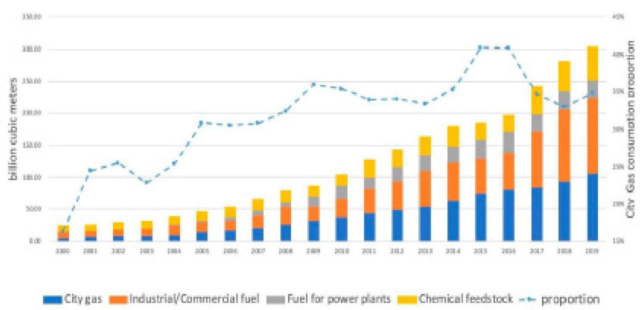

Fig.1. Natural Gas Consumption Structure in China.
Source: Gastank and National Bureau of Statistics of China

countries and territories.

Overview of China's pre-COVID-19 natural gas market

Natural gas consumption

According to the City Statistical Yearbook, China's natural gas is used in the industrial, residential, transport and other sectors (Liu et al., 2018). In 2015, some 285.6 million people had access to gas. The National Energy Administration of China forecast consumption of 360bcm in 2020; approximately 10% of China's total energy demand (Liu et al., 2018).

Residential natural gas consumption is the main driver of growth of China's natural gas demand due mainly to recent national energy policies such as the coal-to-gas reform and urbanization intensification. Fig. 1 shows that city natural gas consumption accounted for approximately 19% in 2000 and 41% in 2016. However, demand is seasonal and related mainly to demand for winter heating (Liu et al., 2018). Liu et al. (2018) suggest that the price elasticity of residential gas consumption is -0.895. Studies of the determinants of gas consumption growth in China identify economic growth, urban population growth, industrial structure, energy efficiency and export of goods and services (Deng, 2019).

Natural gas production and importation

China is ranked sixth for world gas production. Domestic production has not kept pace with demand resulting in China being the third-largest gas importer and the second-largest importer of LNG. In the last 10 years, dependence on imports rose to above 40% from effectively zero (O'Sullivan, 2018) and is set to increase further. Although China is the world's largest energy market, natural gas represents a small share of its energy supply. To try to reduce pollution, the government wants to increase this share to 10% in 2020 and 15% by 2030, and to make this law[2]. To increase this share would require market deregulation and a lower price but that would reduce the incentive for local investment in production and further aggravate dependency.

In 2019 the U.S. became the top oil and gas producing country with a market share of 18% (up from 16%) compared to Russia 16% and Saudi Arabia 15%[3], which resulted in a buyers' market. Based on Europe's success in obtaining more favorable terms from Russia, China seems to be able to make demands based on its pivotal position as a major buyer. Achieving more favorable pricing would counterbalance its dependence on imports and reduce the importance of this issue.

Price and market dynamics

Natural gas price fluctuations have been small for some time due to reduced global demand[4] and the recent warm winter. Global gas companies with excess supply of LNG now have to face the COVID-19 pandemic and oil price fluctuations. All of these issues will extend and increase the current imbalance between supply and demand for LNG. Up to 8% (over 25mtpa) of global LNG demand could be at risk in the near term while the low prices could continue for 12-24 months. LNG buyers may be able temporarily to capitalize on these low prices to improve contract terms and allow substitution from coal to gas.

The fall in China's demand for natural gas has yet to be investigated. Total imports rose 9.6% in 2019, and pre- COVID-19, growth in Beijing's demand for natural gas for 2020 was estimated by the China National Petroleum Corp (CNPC) to be 8.6%. However, the major economic slowdown caused by COVID-19 is decreasing production. At the beginning of March, Reuters claimed

Month	City Gas	Industrial	Power	Chemical Feedstock
Jan 19	46.7%	27.9%	19.5%	5.9%
Feb 19	45.8%	28.2%	17.7%	8.3%
Mar 19	36.1%	35.1%	19.4%	9.4%
.	.	.	.	.
Dec 19	47.9%	30.0%	16.3%	5.8%
Jan 20	49.8%	26.1%	16.9%	7.2%
Feb 20	54.5%	21.3%	16.8%	7.4%

Table 1: China's Monthly Natural Gas Consumption Rate by Sector
Source: Gastank

that PetroChina had suspended natural gas imports, issuing *force majeure* clauses to unspecified suppliers of piped natural gas.

4. The impact of COVID-19 on China's gas market

The impact of COVID-19 on China's natural gas market is mixed. We show that reduced industrial

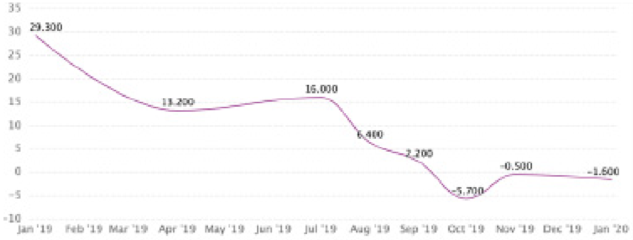

Fig.2. Year-on-year Growth Rate of Natural Gas Imports in China (1 year)

demand is being absorbed by increased household consumption for heating and cooking during the lockdown.

Demand-side impacts

Data from Gastank show a 29% drop in two months (from 30% in December 2019 to 21.3% in February 2020), and a YOY decline in the industrial gas consumption ratio of 1.7 percentage points in January 2020 and 6.9 percentage points in February 2020 due to the lock-down (table 1). This is significant considering the 10 years of consistent growth averaging 16% despite downward growth in the most recent two years which recorded a one-year average monthly growth rate of 15%.

However, overall demand has barely changed. Gastank data collected from gas suppliers and major downstream users show that monthly average daily consumption in February 2020 due to increased demand for household use was 0.83 bcm compared to 0.85 bcm in February 2019. Table 1 column 2 presents combined consumption by residents, public services, heating, compressed natural gas automobiles, and LNG trucks. City gas use tends to drop significantly in February and March when heating needs reduce; however, in February 2020 YOY growth was 17% (from 45.8% to 54.5%), with all users except residents severely affected by the lockdown.

While the LNG market is still expected to grow in the medium-to-long term, growth in demand for LNG is likely to slow this year. Based on past trends, in

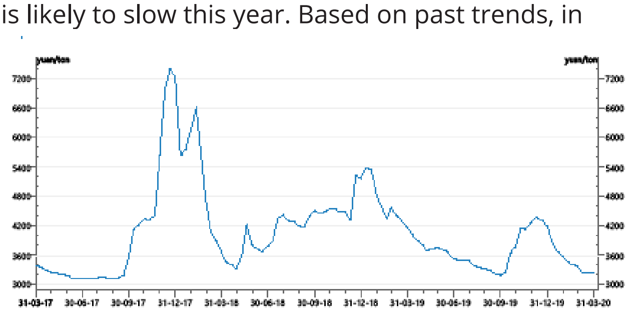

Fig.3. LNG National Market Price in the Last Three Years

Source: WIND and National Bureau of Statistics of China

the short term global demand for LNG is expected to flatten or decline by up to 3% which would result in the LNG market in 2020 being 25mtpa (8%) smaller than previously forecast.

Impact on the supply side and imports

CNOOC (China National Offshore Oil Corporation), China's largest importer of LNG, has suspended several transactions with its main suppliers (see Fig. 2). Economic indicators show that natural gas storage space in China is saturated which situation is set to continue for some time.

Chinese upstream production sites were restricted areas pre-COVID-19 which explains the minimal infections there. Midstream management of the pipes is fully automated and not labor-intensive, and therefore the lockdown did not affect pipeline transportation. Tanker transport was affected only over short periods and mostly in Hubei province and households did not suffer significant shortages. Gas tankers were unable to unload due to lack of storage resulting from the sharp decrease in industry demand for natural gas. Also, the negative effect of COVID-19 on domestic production has been masked by lower international prices. Historically, national oil companies increase production with a lag when international prices are high (O'Sullivan, 2018) because governments set artificially low domestic prices which are unrelated to the world price. The current low world prices do not encourage increased production.

Market dynamics and price effect

While the average price for residents reported by NDRC is within RMB0.02 of the RMB2.62/cu.m. level for July 2019 to February 2020, immediately before the pandemic there was a marked downward trend (see fig.3) in the fully deregulated price for non-resident natural gas used directly for chemical feedstock, power generation, and industrial use. Fig.3 is consistent with deregulation promoting a price spike which was followed by a prolonged period of significant price drops from the end of 2017 with peaks during the winter. The pandemic exacerbated this trend with YOY growth rates of -2.8%, -0.2% and -0.2% in January, February, and March 2020.

There is no mechanism allowing adjustment to already low resident prices in the case of a dramatic event such as COVID-19. In fully deregulated markets the lower prices would have been passed on to customers. If the pandemic continues and prices fall even further below the regulated price, it is unclear whether the benefits can be passed to residents.

Finally, note that disentangling the effect of oil price shocks on economic growth in China is not straightforward. According to Kilian and Vigfusson (2017), little is known about the extent to which oil price shocks explain recessions.

Conclusions and policy implications

As a clean energy, natural gas provides China with economic and social benefits. This paper offers a new perspective on the impact of COVID-19 on China's gas market. It provides insights into various aspects of the gas energy market including energy demand and supply and gas price dynamics. We found a substantial decrease in gas consumption growth and decomposed this effect according to supply chain, production, importation, and consumption. While household consumption increased due to lockdown policies and restrictions on movements, industry consumption decreased sharply. Most significant is that our findings highlight the importance of including the risk of pandemics when predicting gas demand in China.

We offer two main recommendations. First, the urgent need to improve forecasting models to include pandemic and natural disaster events. Second, the importance of ensuring gas production and consumption during lockdown periods. Another pandemic or a second wave of COVID-19 will require new policies. A secure supply chain is paramount for China whose urbanization growth rate is increasing making more households reliant on gas compared to other energy sources.

The current world economic situation is characterized by an elevated level of uncertainty; thus, the results of this analysis should provide valuable insights for policymakers making decisions about efficient policy interventions related to how pandemics shape the structure of the energy market. Our findings should be helpful also to countries implementing energy efficiency policies to achieve a cleaner and low-carbon environment.

Footnotes

[1] A range of methods can be used to forecast gas consumption including the Hubbert curve method, statistical methods, artificial neural networks, grey prediction model, econometric models, mathematical models, simulation techniques, etc. Most of these techniques have been used to forecast gas consumption in China.

[2] Art. 41 Natural Gas Usage of the "PRC's National Energy Law (Draft for Solicitation of Comments)" published April 10, 2020 mandates that the State Council's energy related ministries should increase the ratio of one-time natural gas consumption.

[3] CEIC and OPEC data.

[4] Global demand for natural gas surged by 4.6% in 2018, the fastest growth since 2010 according to the International Energy Agency.

[5] We could have tested the sensitivity of consumption in different especially warmer provinces where more heating would be more likely due to the presence of boilers in many south China apartments. However, we do not have access to recent data.

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Annex

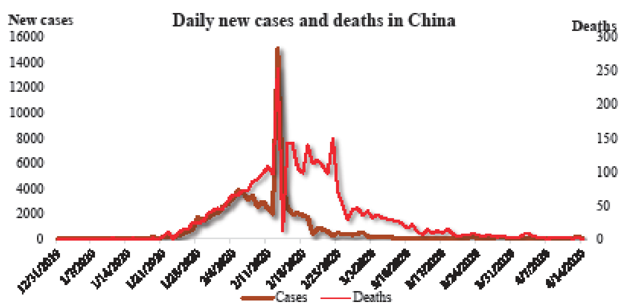

Fig. 4. Daily new cases and deaths in China (31 December 2019-14 April 2020).
Source (EU Open Data Portal)

The aauthors want to thank Professor Lutz Kilian for comments and suggestions on a previous version of this paper. We also thank our informants in the Shanghai Petroleum and Natural Gas Exchange and the Chinese natural gas industry.

Corona Effect on Power Generation in Germany

BY BRUNO BURGER AND CLAUDIA KEMFERT

Power generation in Germany

The German electricity market is characterized by a transformation due to the energy transition (Energiewende) towards an almost full supply with renewable energies. Currently, about 40 % of electricity is still generated from fossil energy sources; especially coal (see Figure 1). The energy transition envisages increasing the share of renewable energies from about 40 % today to 80 % in 2050.[1] The nuclear phase-out envisages that all nuclear power plants currently still in operation will be successively shut down by 2022.

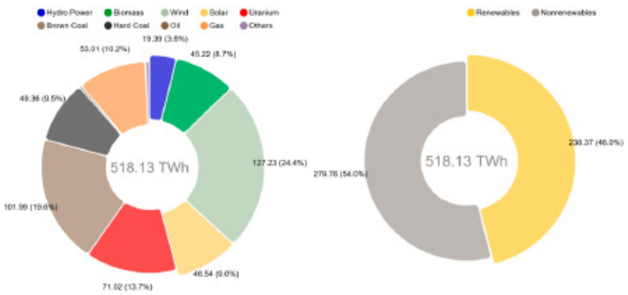

Figure 1: Net public power generation 2019
Source: Fraunhofer ISE; www.energy-charts.de/energy_pie.htm?year=2019

In implementing these goals, Germany is following the EU guidelines. The EU roadmap envisages increasing the share of renewable energies to 80 % by 2050. The[2] EU also aims to reduce greenhouse gases by 80 to 95 % over the same period. This is to be achieved above all by a so-called "de-carbonization" of electricity generation, i.e., the significant increase in renewable energies and the improvement of energy efficiency. Germany has decided to reduce greenhouse gases by 40 % by 2020 compared to 1990. Recently, greenhouse gases have risen slightly; it is feared that the reduction targets will probably not be achieved.[3] The expansion of renewable energies and the improvement of energy efficiency, particularly in the mobility and transport sectors, are the main pillars for achieving the climate targets.

The economic profitability of conventional power plants declines with the expansion of renewable energies. As renewable energies enjoy feed-in priority and produce more and more electricity, the production times of conventional power plants are reduced. On the other hand, the growth of renewable energies leads to falling electricity prices on the stock exchange, due to the so-called merit order effect[4] Power plants that are used at peak load, such as gas-fired power plants, thus lose their economic attractiveness.

Effects of Corona on electricity generation in Germany

In the first quarter of 2020, a significant reduction in coal-fired power generation in Germany is evident for three reasons:
1. high feed-in of wind power,
2.comparatively high CO_2 price and 3. low gas price, which led to a fuel switch from coal to gas-fired power plants. The following overview shows the relative change from the first quarter of 2020 compared to 2019.

The load development in the first quarter of 2020 shows almost no effects of the corona crisis compared to the load in comparable past first quarters

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See footnotes at end of text.

Figure 2: Net public electricity generation in the first quarter 2020
Source: Fraunhofer ISE; www.energy-charts.de/downloads.htm

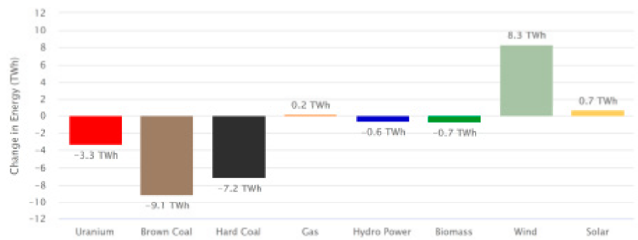

Figure 3: Absolute change in net electricity generation first quarter 2020 and comparison with first quarter 2019
Source: Fraunhofer ISE, www.energy-charts.de/downloads.htm

Figure 4: Load in first quarter 2015 – 2020. The load includes electricity consumption and grid losses, but not pumped electricity consumption and the conventional power plants' own consumption. Source: Fraunhofer ISE; source: www.energy-charts.de/energy_de.htm?source=all-sources

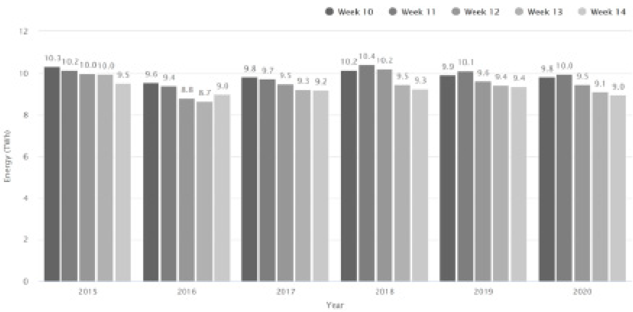

Figure 5: Load in calendar weeks 10 – 14; year 2015 – 2020.
Source: Fraunhofer ISE; source: www.energy-charts.de/energy_de.htm?source=all-sources

of the last years.

Even the weekly load of 2020 shows only small deviations from the loads in the previous years. Corona crisis started in week 12 in Germany. In week 14 the load decrease compared to 2019 is approx. 3%.

Germany's electricity trade balance with other countries shows that absolute exports have declined due to the higher CO_2 prices and the resulting lower profitability of coal-fired power plants compared to gas-fired power plants. This has also led to the fact that it was more economical for neighboring countries to

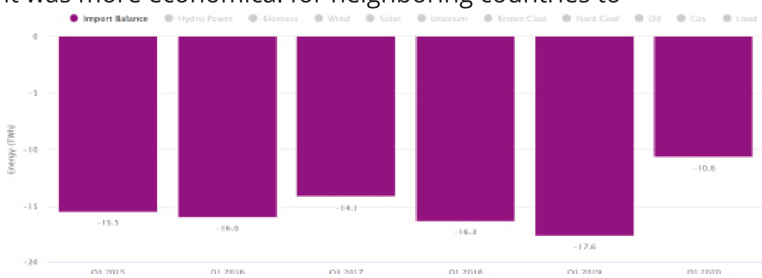

Figure 6: German electricity imports and exports in first quarter 2020 (physical flows). Positive values mean import, negative values mean export.
Source: B. Burger, Fraunhofer ISE; www.energy-charts.de/energy_de.htm

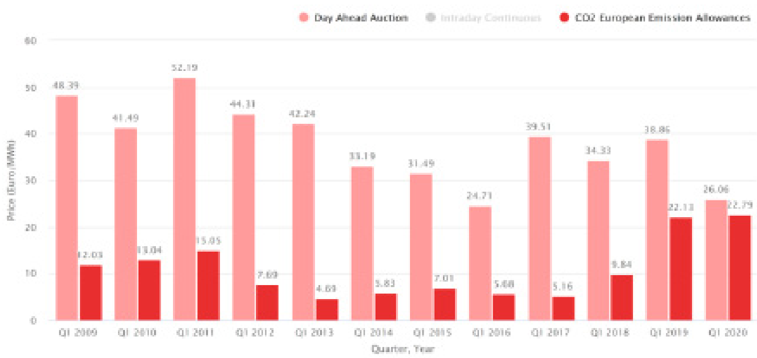

Figure 7: Volume-weighted day ahead spot price and price of CO_2 European Emission Allowances, both not adjusted for inflation.
Source: www.energy-charts.de/downloads.htm

use their own gas-fired power plants largely than to buy lignite-fired electricity from Germany.

Conclusion

So far, only minor effects of the Covid-19 crisis on the electricity market in Germany have been observed. Due to the high share of wind energy, high CO_2 prices and low gas prices, there has been a significant reduction of coal-fired electricity in Germany. Thus, significant emission reductions are also expected.[6] However, the emission reduction effects of the increase in renewable energies compared to coal power might dominate in comparison to possible Covid-19 effects in the transport sector.

However, in this short study only the electricity sector is considered, not other sectors such as buildings or transport. As CO_2 prices have fallen sharply because of the further Covid-19 crisis, the capacity utilization of coal-fired power plants in particular may change again in the further course of time. However, a significant reduction in electricity demand may also be expected as a result of the shutdown. The further effects will be observed with suspense.

Footnotes

[1] See Child et al (2019), Gerbaulet et al (2019), Kemfert (2019)

[2] Cf. EU Commission 2011.

[3] Cf. UBA 2019

[4] The expansion of renewable energies causes an increase in supply and thus a shift of the supply curve to the right, so that a price reduction occurs with unchanged demand, see ISI/ DIW/ GWS/ IZES 2011, p. 15, for more details also the contribution of Möst/ Müller/ Schubert.

[5]

[6] According to a first preliminary estimate, Agora Energiewende holds out the prospect of achieving the climate targets for 2020 Cf. Hein et al (2020) https://www.agora-energiewende.de/fileadmin2/Projekte/2020/_ohne_Projekt/2020-03_Corona_Krise/178_A-EW_Corona-Drop_WEB.pdf

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Going 'Green' During the COVID-19 Crisis

BY RANJEETA MISHRA AND DINA AZHGALIYEVA

COVID-19, as both a supply shock and a demand shock, has the potential to severely disrupt global economic activities, including energy systems. According to IEA (2020), global energy demand is expected to decline in 2020 with widespread travel restrictions and economic lockdowns as COVID-19 spreads around the world. Japan reported it's first case of COVID-19 in January 2020; however, did not impose any major lockdown (except Hokkaido prefecture for few weeks). This is good enough to assume that the energy demand in the country has not been strongly affected due to COVID-19. Experts are increasingly acknowledging that the global solar PV value chain is particularly affected because manufacturing capacity is concentrated in few countries, including the People's Republic of China (Zhai, 20202). Given these facts and high dependence of Japan on the People's Republic of China for its solar PV supply, it would be interesting to look at the trend in energy imports to the country.

Due to limited data to evaluate the impact of COVID-19 on energy trade in Japan, we use imports of solar PV provided by the Trade Statistics of *Japan* Ministry Japan. Although solar power was only 7% of total power generation, solar power was one-third of power from renewable sources in Japan in 2018. Given this high share of solar power in renewable energy sources, disruption in the availability of solar PV may have adverse consequences on the sustainability of the renewable energy power generation. It is interesting to note that the fossil fuels are still a

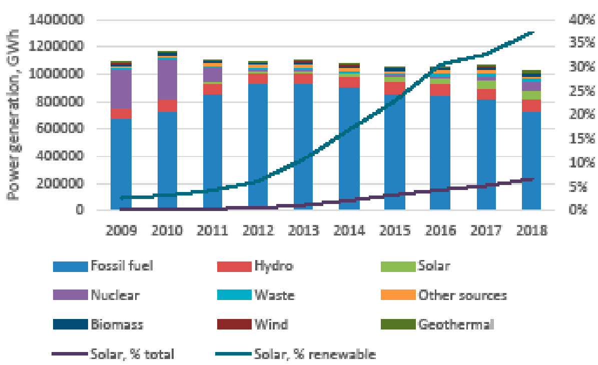

Figure 1 Power generation mix in Japan

Source: Own elaboration using data from IEA/OECD World Energy Balances/Extended World Energy Balances

dominant source of electricity in Japan's power mix, solar power generation started to grow faster in 2012 when the government launched the feed-in-tariff scheme (JEPIC 2019).

Import of Solar PV in Japan

Using monthly imports of Solar panels in Japan for the period January 2019 to February 2020 (the latest available data as of 17 April 2020), we analyze the trend in energy trade. Our preliminary findings suggest the import of a solar PV was stagnant over the last few months; however, it significantly decreased during the COVID-19 outbreak (Figure 2). The People's Republic of China and Taiwan are two major exporters of solar PV to Japan which accounted for 87% of its total imports in 2019.

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The People's Republic of China was severely affected by COVID-19 starting from January 2020, which could have affected local production and exports of solar PV. This raised concerns how supply of solar PV will be affected.

The share of imports of solar PV from the People's Republic of China to Japan reduced by more than half in February 2020 compared to the previous month. Fortunately, another major exporter of solar PV to Japan, Taiwan, was not severely affected by COVID-19. Part of the reduced supply of solar PV from the People's Republic of China was replaced by Taiwan. The share of imports of solar PV from Taiwan to Japan increased in February 2020. Compared to the imports during the same months last year, the share of the People's Republic of China to Japan shows a decline (figure 3). This also confirms that this decline during the recent months is not just seasonal. These evidences suggest that this early decline in imports in the wake of COVID-19 is mostly likely to be supply-driven. Only

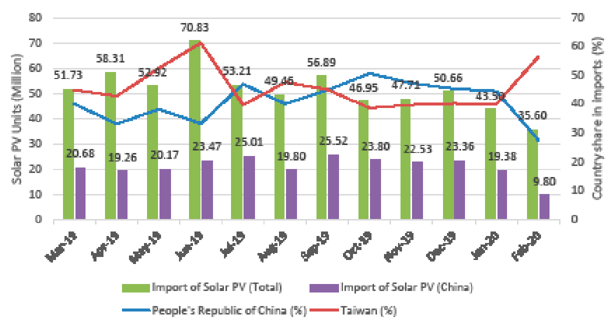

Figure 2 Import of Solar PV

Source: Own elaboration using data from Trade Statistics of Japan Ministry of Finance

one month of lower imports of solar PV to Japan does not challenge energy supply in Japan significantly due to the accumulated capacity stock of solar PV in Japan and low share of solar PV power in total electricity generation (only 7% in 2018). Nevertheless, it raises a concern for further development of solar PV capacity stock and transition towards sustainable energy

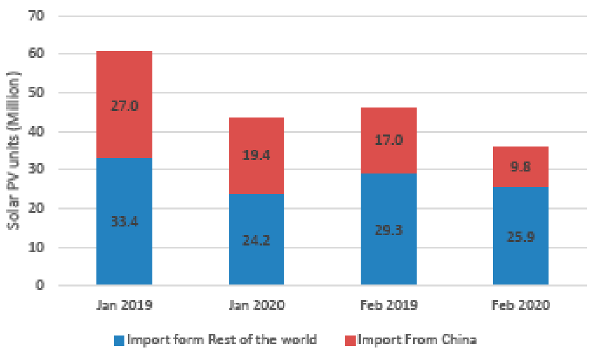

Figure 3 Change in Imports of Solar PV during the same period last year
Source: Own elaboration using data from Trade Statistics of Japan Ministry of

systems if import of solar PV continues to be disrupted due to the COVID-19 outbreak.

Policy Recommendations

In line with Bhandari and Roy (2020), we recommend that tackling sustainable energy issues along with the COVID-19 pandemic crisis together can strengthen resilience through its environmental impact. This requires a coherent policy formulation minimizing the effects of the pandemic in the short-run and supporting energy sustainability in the long-run.

Before been overtaken by Chinese rival, Japan was leading the Japanese solar panel industries until the latter half of the 2000s (Ohira 2017). The Japanese customers are still dependent on the domestic manufacturers for housing needs of solar PV. As every crisis also brings with its new opportunities, the current crisis shall also be considered as an opportunity to consider making the domestic manufacturing cost-competitive to reduce the dependency on one production source. This kind of diversification would be helpful in reducing the risks and making the sustainable energy supply chain more resilient to shocks.

In a similar vein, the current fiscal stimulus package offered by the Japanese government to mitigate the disruptions in the supply chains also includes USD 2.2 billion to the manufacturers to shift the production out of China to other Southeast Asian countries (Reynolds and Urabe 2020). As there is too much dependence on a single largest supplier for renewable energy, a more specific plan is needed for the diversification, especially focusing on this sector.

As the diversification of the renewable energy supply chain would be gradual and a long-term process, the cost competitiveness would require making use of the comparative advantage due to low labor cost. Transfer of technology and technical know-how to the developing countries would be helpful in expediting the whole process.

Conclusions

Through this article, we attempt to capture the early impact of COVID-19 on energy and energy technology trade, that provides lessons for energy-importing countries, including Japan and its implication on the nature of trade network in the sector. Japan majorly imports solar PVs from China and Taiwan. The months following the outbreak of COVID-19 in the People's Republic of China has witnessed a remarkable change in the market share of solar PVs in Japan going in favor of Taiwan away from the People's Republic of China. We argued that limited number to import partners for energy and energy technology trade can have important implications for energy security following a crisis. Specifically, we suggest that apart for promoting domestic production of low-cost solar PV, the increased diversity in energy and energy technology trade partners through formation of regional trade cooperation and extending technical and financial support and to the global south can be mutually beneficial for both importing as well as exporting counties.

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The Economic Costs of Forecasting Errors in the PJM Interconnection Due to the COVID-19 Quarantine

BY DYLAN BREWER

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See footnotes at end of text.

Introduction

Doors are closed, lights are off, and normally busy rooms are silent in businesses around the world as individuals stay home and workplaces shut down to prevent the spread of COVID-19. Economic activity has declined significantly—and as a result, commercial and industrial demand for electricity have also declined. More people at home means increased residential demand for electricity, but preliminary data show that total electricity load has fallen nearly 10% in the U.S. and Europe, and the wholesale price of electricity in India is approaching an all-time low[1]. How has the decline in electricity demand affected electricity markets?

This unforeseen decline in electricity demand has disrupted electricity demand forecasts, increasing the costs of supplying electric power. On the grid, electricity supply (generation) and demand (load) must be balanced in real-time within a small band in order to avoid power disruptions. Because of this real-time balance, grid operators and utilities rely on forecasts of electricity demand in order to procure commitments in the day-ahead market from suppliers to generate the right amount of electricity at the right time. If the forecast predicts electricity demand will be low when it is high, the grid operator must procure "adjustment" generation at a higher cost to cover the extra demand. If the forecast predicts electricity demand will be high when it is low, the grid operator will have purchased too much electricity generation in the day-ahead market, increasing the price.

The declines in demand due to COVID-19 represent a massive shift in electricity load patterns, disrupting the accuracy of the day-ahead forecast. This article uses hourly data from the PJM Interconnection (PJM) to analyze the performance of the day-ahead load forecast during the COVID-19 period. First, I show that after matching on weather, day-of-week, and time-of-day, PJM electricity consumption during the COVID-19 period relative to the beginning of the year has declined 10.6%. Next, I show that PJM's day-ahead forecast error jumps to 3% on average during the COVID-19 period, on par with the worst performance of electricity forecasting models in the last five years. In addition, it appears that the forecast did not improve in the first week of April relative to March. Because of relatively mild temperatures in March and April 2020, the cost of forecast error is likely to be small; however, failure to adjust forecasting models could prove costly as the quarantine continues and temperatures warm.

The day ahead market and load forecasting in PJM

PJM is a U.S. regional transmission organization that operates a wholesale electricity market and transmission system serving parts of the Mid-Atlantic and Midwest regions. To purchase commitments of electricity generating capacity, PJM operates a wholesale day-ahead market in which generators bid to provide electricity and utilities bid to withdraw electricity in each hour of the following day. Each supplier bid stipulates the amount of generation (in MWh) offered during an hour and a minimum price required for the generator to operate. Each demand bid stipulates the amount of load (in MWh) and the maximum price required—in practice many bids do not specify a maximum price.

Bidding in the day-ahead market occurs the seven days prior to the day of generation. The day-ahead market closes at 10:30 AM ET the day prior to generation (PJM, 2017). Upon close, the market operator orders the bids from lowest price to highest price to create a supply or offer curve and accepts the bids required to meet demand. This ensures that the lowest-bid generating units are used to provide electricity.

Because it is impossible to know demand the next day, utilities purchasing electricity must forecast their load based upon their expectation of the next day's electricity demand. weather and economic activity. Typical load forecasts are based upon lagged load, forecasted weather (especially temperature), and time-of-day indicator variables meant to capture human and economic activity (see e.g., McCulloch and Ignatieva, 2020).

An extreme and novel event such as COVID-19 can break the link between past load and future load, causing forecasts to perform poorly. Fundamentally, forecasts predict future electricity load based upon the patterns observed in past load and thus rely on the assumption that future load patterns are comparable to what has been seen before. When an extreme event occurs, the relationship between the outcome variable and predictor variables can change. A statistician would say that the underlying data generating process has changed, degrading the performance of the forecast; others would liken the scenario to using a roadmap that is 10 years old or even flying in the dark.

Change in load during the COVID-19 period

How dramatically have electricity loads changed in PJM due to COVID-19? Between March 15th and April 4th, more than 10 percent of U.S. workers applied for unemployment benefits (Gould and Shierholz, 2020). Every state in the PJM area has a shelter-in-place order in effect (Key, 2020), and most schools and workplaces have switched to remote operation when applicable.

Many more households are at home during the day—either unemployed or working from home—and many industrial and commercial sites are unoccupied. One would thus expect overall load to decline due to decreased economic activity and for the load profile to change as schedules become more flexible.

To test these hypotheses, I examine hourly-metered load data from PJM and hourly weather data (temperature, dew point, precipitation, and snow depth) from NOAA's Integrated Surface Database from January 1, 2014 to April 7, 2020. I map weather stations to PJM's electricity transmission zones using weights published by PJM (PJM, 2018). It is important to control for weather to be sure that any pattern in electricity

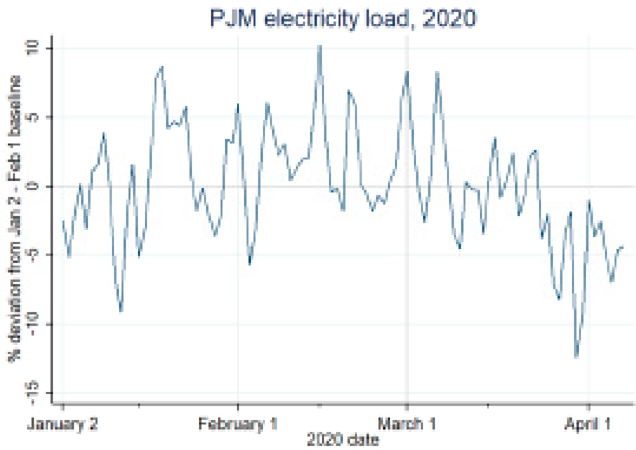

Figure 1: PJM hourly electricity load, controlling for weather, month-of-year, day-of-week, and hour-of-day variation. Presented at the average daily level and normalized to deviations from zero for the baseline period January 2nd - February 29th.

consumption observed in March and April 2020 is not being caused by changing weather.

Figure 1 plots total load in PJM from January 2nd to April 7th, 2020, controlling for the weather in each of PJM's zones, month-of-year, day-of-week, and hour-of-day variation in

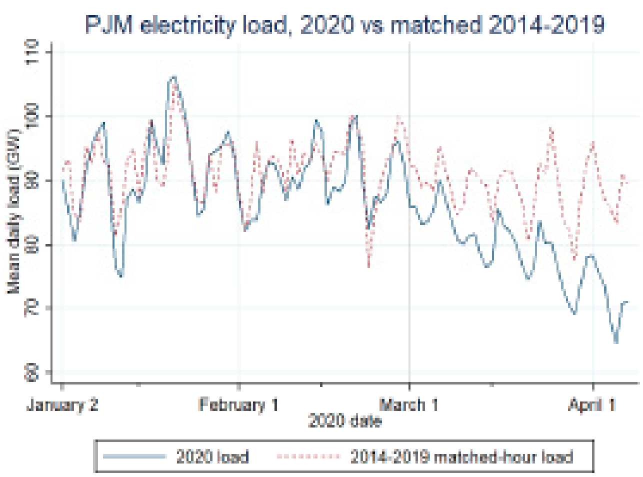

Figure 2: Raw electricity load matched to the most-similar weather hour from the previous five years, matching exactly on the hour-of-day and day-of-week.

load patterns.[2] A slight trend break can be seen around March 1st, but there is still a lot of residual noise in the series and it is difficult to make concrete statements about the size of the change in electricity consumption.

Another way to see the change in demand patterns is to compare March and April 2020 electricity consumption to similar-weather hours from prior years. Figure 2 plots the raw load data from 2020 versus similar-weather hours from 2014-2019. While electricity demand was fairly normal for the first two months of the year, a clear and growing decrease in load can be seen beginning around March 1st. To construct this figure, I match each hour of electricity demand in 2020 to the most-similar weather hour from the previous five years, matching exactly on the hour-of-day and day-of-week[3]. For example, I compare the hour on Wednesday April 1st from 12-1pm to all Wednesday 12-1pm hours in the first four months of 2014 to 2019 and match it to the hour with the most

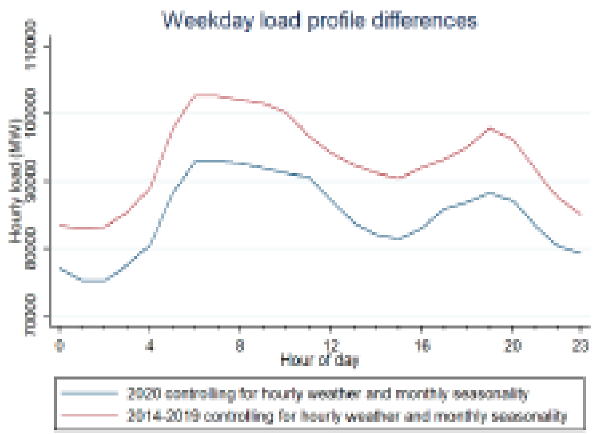

Figure 3: Average March and April weekday load by hour-of-day, controlling for weather and monthly seasonality.

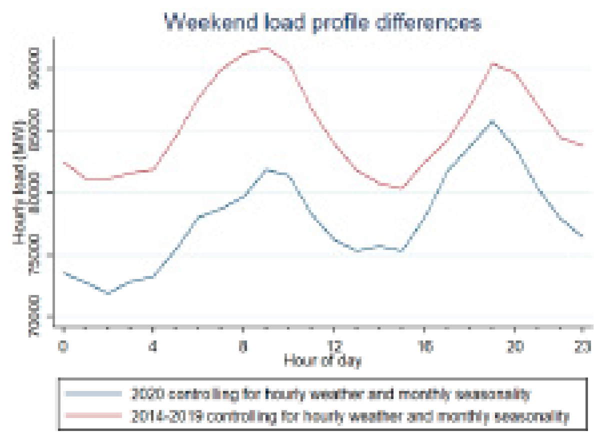

Figure 4: Average March and April weekend load by hour-of-day, controlling for weather and monthly seasonality.

similar weather. Overall, the difference in average PJM electricity consumption during the COVID-19 period from March 1st to April 7th relative to the matched baseline is 10.6% lower than this difference between January 2nd and February 29th.[4]

Finally, one would expect intra-day load patterns to change given the spike in unemployment and work-from-home responses. Figures 3 and 4 plot the average electricity use for each hour of March and early April 2020 and each hour of March and April on weekdays and weekends for the prior five years, controlling for hourly weather variation and monthly seasonality. Surprisingly, while there is a mean-shift in hourly load, it is difficult to detect any change in patterns other than a slight elongation and flattening of the mid-morning peak.

Forecasting error

While each bidder's forecasting method is private and their day-ahead bids are kept confidential for six months, PJM constructs and releases an independent public forecast that is likely similar to forecasts used by bidders (or may be an input to private forecasts). The forecast uses a mix of prediction algorithms (including three different neural nets, a matching algorithm, and time-series regression) created both in-house and by a third-party vendor (Anastasio, 2017). The forecasting team often uses a weighted average of each algorithm's prediction but has found that different algorithms work better for extreme-weather days and holidays. PJM's day-ahead forecast updates every half hour on the quarter; thus, the final two forecasts before the day-ahead market closes update at 9:45 AM ET and 10:15 ET. PJM's database contains historical 9:45 AM forecasts. I examine the performance of PJM's 9:45 AM forecast in March 2020 versus its historical performance to understand how well prediction models are performing given the COVID-19 shock to electricity load.

I consider two measures of forecasting error. The first measure is the mean percent prediction error, which is simply the absolute hourly forecasting error as a percent of load, averaged by month. This measure captures the relative performance of PJM's prediction algorithm in the COVID-19 period relative to its past performance. The top panel of Figure 5 displays monthly average percent prediction errors from PJM's forecast from January 2014 through April 2020. March 2020 was the fourth-worst forecasting month in six years while the beginning of April 2020 is on track to be the worst forecasting month in six years by mean percent prediction error. While not displayed in this article, controlling for weather increases the March and April relative forecasting error size.

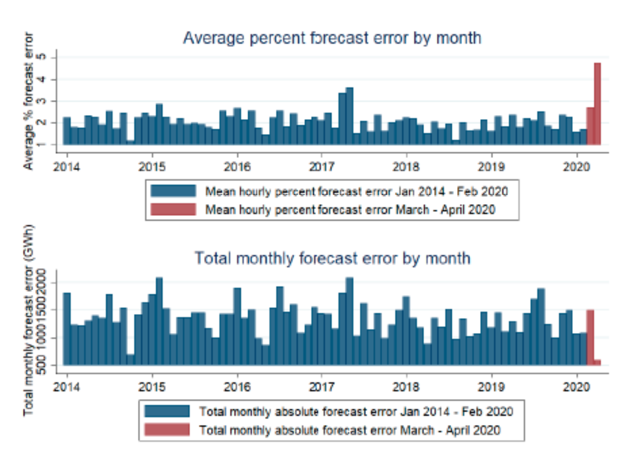

Figure 5: Mean hourly percent forecast error by month (top) and total absolute forecast error by month (bottom) from January 1, 2014 though April 7, 2020.

The second measure of forecasting error is the sum of absolute prediction error, which is simply the total absolute hourly forecasting error. This measure roughly corresponds to the relative economic costs of the forecasting error in PJM during the COVID-19 period because it reflects the size of the missed predictions. The bottom panel of Figure 5 displays total monthly prediction errors from PJM's forecast from January 2014 through April 2020. Despite the large percentage error, the total absolute forecast error is relatively small because March is a relatively low-demand month for electricity and April has only begun. Even though the forecast is performing poorly, the cost of the error is relatively small. Of the 76 months since January 2014, March 2020 had the 23rd-highest total absolute forecasting error.

Conclusions

Self-quarantine efforts in response to COVID-19 have induced a 10 percent decline in PJM electricity load from March 1st through April 7th relative to baseline levels when accounting for weather, hourly, and monthly variation. This sudden change in the underlying data-generating process for electricity load has reduced the predictive power of PJM's day-ahead forecast. The forecasting model performed poorly relative to previous performance—March 2020 was the forecast's fourth-worst month in terms of percent absolute forecast error. Despite this, it is likely that over-procurement of generation in the day-ahead market was small due to the relatively low electricity load in March 2020. Failure to adjust forecasting models (or for the learning-based algorithms to self-adjust) may become more costly as summer loads increase.

As of the first week, April's forecasting error is on track to be the worst in recent history, thus it is not clear whether the model is improving. An adjustment to a complex forecasting model is not simple. It requires human time to experiment with changes to underlying parameters of the model and significant computation time. In addition, electricity load patterns continue to change as conditions change, so it is possible that new forecasts would soon be obsolete. Forecasts with increased weight on recent dates (during the COVID-19 period) may perform better, but this may not prove true as the seasons change from spring to summer and conditions continue to change

Footnotes

[1] US: https://www.nytimes.com/interactive/2020/04/08/upshot/electricity-usage-predict-coronavirus-recession.html. Europe: https://www.wsj.com/articles/plunge-in-italys-electricity-use-hints-at-coronavirus-risks-facing-u-s-11584532801. India: https://economictimes.indiatimes.com/industry/energy/power/power-demand-drops-as-offices-stay-plugged-out/articleshow/74819188.cms?from=mdr.

[2] This method is similar to that taken by Steve Cicala in his analysis

described by Bui and Wolfers (2020).

[3] Matching up to the ten most-comparable hours does not substantially change the results.

[4] This estimate is the difference-in-predicted-differences estimate, similar to the estimators considered in Burlig et. al (2020).

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Life after COVID-19: Independent Shale Oil Producers

BY ELEANOR MORRISON

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At the start of 2020, the United States triumphantly took over the title of the largest oil and gas producer in the world, at 13 million barrels per day, supported largely by unconventional production sources. This confirmed the impressive track record of independent shale oil producers, shown to be resilient to previous price collapse situations and continued to grow, under lower costs structures and higher operational efficiencies. Despite the production growth amid strong oil price dynamics providing profitable returns over the past few years, oil and gas equity performance has been under pressure. Analysts and investors have been monitoring the small to medium sized independent shale oil producers' performance, as questions remained on the survivability of the business model, as the production sector matured.

The impact of global governments' response to the coronavirus outbreak, parallel with the Saudi-Russian price war, caused a steep decline in oil prices. The rapidity and magnitude of this global demand shock has never been observed in modern day oil markets. Futures prices at the WTI benchmark for the May 2020 prompt contract fell to below ten dollars and briefly into first-time negative territory. With global storage facilities full and supply shut-ins lagging the extraordinary collapse in demand, these historically low prices are expected to remain in the short term. Once the pandemic subsides, the demand-supply equilibrium depends on the length and ultimate depth of the disruption to economic activity.

The timing of this global negative demand shock arrived as investors' faith in shale oil producer economics was tested. In response to plummeting global oil prices, U.S. fracking experienced a large decline between February 2020 to April 2020, currently running at 60% lower started fracturing operations since the start of the year[1]. Hurried shut-ins were in response to cancelled customer contracts and uneconomical market prices. In an environment with no new fracking wells coming to market, there could be up to three million barrels per day lower production by year end[2]. Restructuring advisors have been engaged in attempts to create survival trajectories for many small to medium sized independent producers. Low cost funding supported the recovery of shale oil producers after the 2014 price collapse, resulting in the current large debt positions on corporate balance sheets.

Independent shale oil producers have comprehensive derivative hedging programs to limit downside market risk exposure, usually mandated by loan covenants and implemented by risk managers. Producer oil price hedges are based on expected annual production in future years. At the start of the year, approximately 50% of the 2020 production was hedged and a significantly lesser volume for 2021 production[3]. Many of the hedge instruments used by shale producers are three-way collars, which provide a false sense of protection, in that under large price collapses the hedge is ineffective. To reduce the cost of hedging, many producers enter into this three-way collars strategy, which is the combination of a traditional collar, long put option and short call option, plus a short put option at a much lower out-of-the-money price level. Under a massive price collapse, producers are left without a floor protection, as was last observed in the 2014 low price event. Future risk management programs should limit the use of three-way collars, given the failed price protection observed in 2014 and again this year, and review the additional cost of upfront funding of standard collar hedging program.

The preference of investors for independent shale oil corporates was supported by wells offering faster returns, because of high initial production rates, compared to conventional oil producers. In the drive to grow and satisfy investors, shale oil operators have moved to costlier capital expenditure strategies, to develop superlateral well designs, which source oil faster with a lower unit cost. This trend is moving many producers from industrial turnkey operations, towards the traditional capital intensive driller structures, which further depletes their cash reserves.

The expected trajectory for global demand return is unknown and will probably not be uniform across all industrial sectors. Governments have yet to determine appropriate policies and timelines for the economy to enable societies to return to a business as usual operating environment. It will take time for the global oil storage glut to recede under a return of demand pattern and a new OPEC+ production policy. The independent shale oil producers, who successfully hedged and survived this price downturn, will be challenged to secure investor support, when profitable oil price economics return. This time, investors may not be as supportive of independent shale oil producers, who still have yet to demonstrate the expectation of a positive cash flow performance. Opportunistic acquisitions in key shale oil field locations, such as the Permian basin, or based on a corporate hedge book, will be expected once corporate valuations are deliberated. Shale oil production will eventually return to domestic supply channels, but under market consolidation.

Footnotes

1 U.S. Fracturing set for biggest monthly decline in history, Oil and Gas Journal, April 22, 2020.

2 Ibid.

3 U.S. shale companies hedges were inadequate for oil price crash, Devika Krishna Kumar and Liz Hampton, Reuters, March 13, 2020.

Short and Long Run Effects of COVID-19 on the Hospitality Industry and the Potential Effects on Jet Fuel Markets

BY ADEL BEN YOUSSEF, ADELINA ZEQIRI AND BUT DEDAJ,

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Introduction

This paper aims to investigate the short and long run effects of COVID-19 on the hospitality industry and the potential effects on the jet fuel market.

The potential impacts of COVID-19 on energy markets (Maijama et al. 2020; Albulescu 2020b; 2020a) has been analyzed by examining the impact on the demand for energy and oil prices but the impact on the hospitality industry (Ying et al. 2020; Jamal and Budke 2020; Lau et al. 2020) tends to focus on the link between the COVID-19pandemicand Chinese tourism. To our knowledge, there are no investigations of the impact of COVID-19 on the hospitality industry and the jet fuel market.

Our paper tries to fill this gap and makes the following contributions. *First*, it examines the short run effects of COVID-19 on the hospitality industry and demand for jet fuel. We examine the effect on airlines, and changes to demand for jet fuel and jet fuel prices. While the duration of COVID-19 is still unknown, our main findings shows that the hospitality industry is deeply impacted in the short term. Implementation of measures to slow the spread of COVID-19 have caused the tourism industry to collapse. Demand for jet fuel has decreased, and prices have fallen. From January to April, the price of U.S. Gulf Coast kerosene fell about 58% . *Second,* it provides an overview of the potential long run effects of COVID-19 on the hospitality sector and the jet fuel market which are likely to be affected also by Hospitality Industry 4.0 and changes to consumer behaviors.

The paper is organized as follows: section 2 discusses the context of COVID-19 and its effect on the hospitality industry, sections 3 and 4 examine the respective short and long run impacts of COVID-19 on the hospitality industry and the potential consequences for jet fuel demand, and section 5 provides some conclusions.

Context

Coronavirus 2019 or COVID-19 is a new infectious disease first identified in December 2019 in Wuhan, capital of China's Hubei province. It spread rapidly across Asia and worldwide, causing a global public health crisis within a short period of time. On March 11, the World Health Organization declared COVID-19 a pandemic. Several measures including national lockdowns and school closures have been implemented to slow the spread of COVID-19.

Tourism accounts for 10% of world GDP and jobs (WEF, 2020) and is among the sectors worst affected by COVID-19. The hospitality industry is in crisis due to worldwide panic about COVID-19 whose duration and scope are still unknown. Many countries which depend heavily on tourism are experiencing a devastating economic blow. However, the impact of COVID-19 on tourism is a global concern; passenger numbers have decreased dramatically, trips have been canceled, and major public events have been canceled or postponed putting many jobs at risk and causing much decreased revenue from tourism. According to the World Travel and Tourism Council (2020), up to 75 million jobs are at risk and this figure could change as the virus evolves which would cause huge loss to the world economy.

UNWTO (2020) made an initial assessment based on the 2003 SARS scenario, on the size and dynamics of global travel and current disruptions, and the geographic spread of COVID-19 and its potential economic impact. It estimates (UNWTO, 2020) that global international tourist arrivals could decline by between 1% and 3% in 2020 compared to an early January 2020 forecast increase of 3% to 4%.

Given the major impact on the hospitality industry of COVID-19, the jet fuel market will also suffer. Fewer flights will result in lower demand for jet fuel. In the succeeding sections we describe in more detail the effect of COVID-19 on the hospitality sector and the potential consequences for jet fuel demand in the short and long runs.

Short run impacts of COVID on the hospitality industry and the potential consequences for jet fuel demand

Dramatic fall in flights

The first cancellations of commercial flights occurred in Wuhan, China. Since restricting travel seems to be effective, many countries around the world have implemented similar measures to slow the spread of COVID-19. Fig. 1 shows the changes to the number of total and commercial flights per day between January 13 and April 11.

According to Flight Radar 24 data, the number of daily flights on January 13 was 171,632 and this had dropped to 62,592 on April 11 - a 64% decrease over three months. On January 13 the number of daily commercial flights was 112,827 falling to 24,975 on April 11 – a decrease of around 77% in three months. In fig. 1, the vertical lines indicate the dates when the U.S., Germany, France, Italy, Spain and the U.K. introduced travel restrictions after which the number of flights fell sharply.

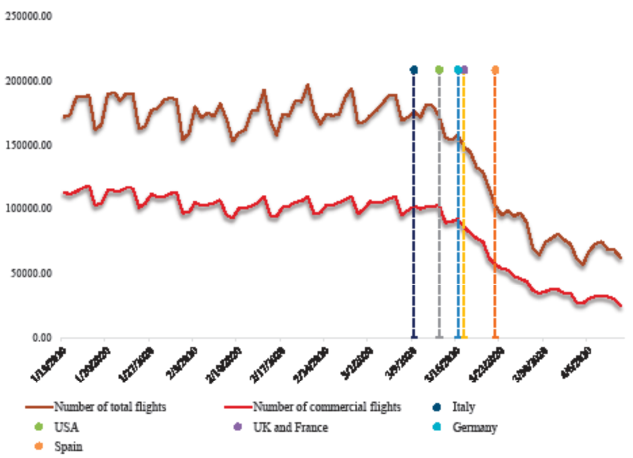

Figure 1. Total daily flights and commercial flights

Many airlines are now facing heavy cost cuts, layoffs of large numbers of employees and closure of many non-essential routes. IATA (2020a) made an assessment based on the scenario that severe travel restrictions could remain in place for three months. This would mean a fall in full year passenger revenues of $252 billion compared to 2019 and a fall in demand of 38% which would have a severe impact and result in demand in the second quarter of 2020 falling by 71% and a net loss of $39 billion. At the same time, the aviation sector is liable for "unavoidable costs" including reimbursement of tickets sold for flights that have been cancelled, accounting for around $39 billion.

On April 14, IATA (2020b) published an updated analysis showing that airline passenger revenues drop by $314 billion in 2020, a 55% decline compared to 2019. These figures reflect the effects of severe domestic restrictions lasting for three months, some restrictions on international travel extending beyond the initial three months and a severe impact worldwide. In Q2-2020, $61 billion of airline cash balances could be burned. COVID-19 will have drastic consequences for the hospitality industry since the companies in the sector are receiving no revenue and therefore have no cash.

Demand for jet fuel

COVID-19 has hit the energy market hard. Demand for fuel and oil products has decreased and prices have fallen. Among the different fuel markets, we expect jet fuel to be affected the most due to the mass suspension of flights which has had a direct impact on demand for jet fuel. According to Rystad Energy (2020), current global jet fuel demand has fallen by almost 31% year-on-year or by at least 2.2 million barrels per day. Demand for jet fuel in 2019 was around 7.2 million barrels per day while Rystad Energy (2020) predict jet fuel demand in April 2020 to be around 2.6 million barrels per day and in May to be about 2.4 million barrels per day.

The cost of jet kerosene continues to fall with flight numbers. Fig. 2 shows the number of total daily flights worldwide and the U.S. Gulf Coast kerosene price ($/gallon). After the imposition of travel restriction by many countries (fig. 2 shows the start dates of travel restrictions imposed by Italy, the U.S., Germany, the U.K., France and Spain), there was a dramatic fall in flights and jet kerosene prices. According to the Energy Information Administration (EIA) data (see fig. 2), on January 13 the price of U.S. Gulf Coast kerosene was $1.821 per gallon, falling to $0.765 per gallon on April

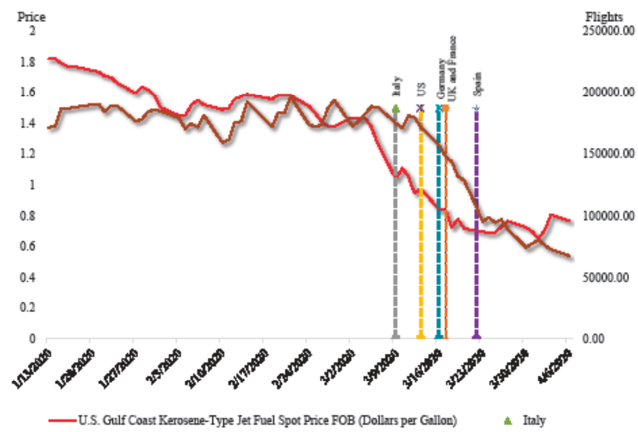

Figure 2. U.S. Gulf Coast Kerosene-Type Jet Fuel SPot Price FOB (Dollars per Gallon) and number of total daily flights

6. From January to April, the price of U.S. Gulf Coast kerosene fell by about 58% with the lowest level reached on April 1 ($0.65 per gallon). The price of jet kerosene is linked to air traffic: low air traffic levels reduce demand for jet kerosene which results in a price fall.

Fig. 3 shows the weekly price of U.S. Gulf Coast kerosene from April 2019 to April 2020 based on EIA data. The biggest fall was in March-April 2020 but no increases are expected in the coming months since lockdowns are continuing in many countries.

Social distancing will continue to have a major impact on the hospitality industry through the second quarter of this year. As many countries are continuing their quarantine to prevent the spread of COVID-19, tourism, travel and accommodation will continue to suffer. Since the duration of the pandemic is unknown, this summer will not experience an increased number of flights, and consequently, demand for jet fuel will continue to be low.

Long run impacts of COVID on the hospitality industry and the potential consequences for demand for jet fuel

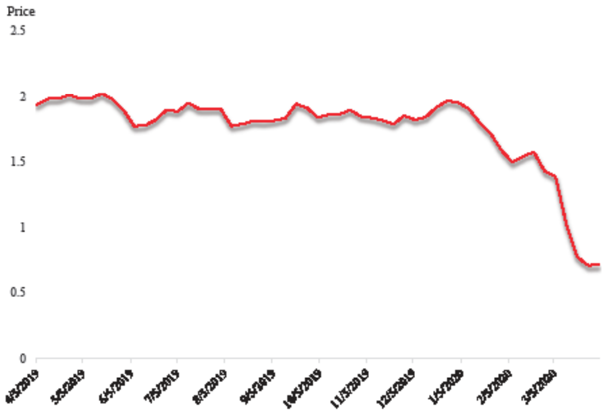

Figure 3. Weekly U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB (Dollars per Gallon)

Hospitality Industry

Increased use of Virtual Tourism

The rapid spread of COVID-19 has resulted in the shutting down of tourism activities around the world. With many world countries continuing their quarantine, airlines are warning of bankruptcy, hotels are closed and tourist buses remain empty. Social distancing has emptied destinations which for many years have suffered from over tourism but despite the lockdowns, would-be travelers can experience virtual tourism. It has been suggested that virtual reality (VR) could substitute for actual travel (Cheong, 1995; Sussmann and Vanhegan, 2000). Over the last few years, the number of VR experiences on offer has grown, and in the present circumstances are being welcomed. Since COVID-19 has rendered travel impossible and tourist attractions have been closed, interest in virtual tours have increased significantly and are expected to continue to grow. Virtual tourism allows customized and accessible information. It enables online visitors to visit museums and a range of attractions, to learn about specific objects of interest, to read blog postings about exhibitions, to read about the history of the attraction they are “visiting”, etc.

Changes to consumers’ preferences (climate change and COVID-19)

The global response to COVID-19 has changed behaviors, resulting in a reduction in greenhouse gas emissions. IATA’s (2020c) most recent economic assessment expects a 38% reduction in air travel in 2020 which would be equal to a 352.7 Mt fall in global civil aviation emissions year-on-year. Previous infectious disease outbreaks such as avian flu in 2005, MERS flu in 2015 and SARS in 2003 caused a decrease in the number of flights but did not result in long-term changes to demand for air travel. Although air traffic decreased briefly during these outbreaks, in each case it recovered within a few months (IATA, 2020c). However, COVID-19 is a new virus and its duration remains unknown. The number of cases of COVID-19 in April 2020 is more than 2 million worldwide and many people are working from home and not traveling. There is a chance that these interim effects and behavioral changes could result in long term shifts which might have a lasting impact on global CO_2 emissions.

What might change?

We know that the pandemic will be controlled at some point but we do not know when. In the meantime, many elements of the hospitality industry will change and it will look different in the future.

First, technology will have an effect on business travel. The emergence of new technologies and their increased use should lead to different air travel behavior in the future. Social distancing has forced many people around the world to work remotely. Conferences are being held online exploiting several available platforms. Zoom a videoconferencing platform, is experiencing record activity resulting in a 100% rise in its stock price since January (Reinicke, 2020). Microsoft’s Teams software has surged in popularity with the addition of 12 million new customers in a single week in March 2020 (Swartz, 2020). Videoconferencing will affect travel especially to far off destinations and will reduce costs and time. Videoconferencing facilities will continue to be used in the long term based on their proven effectiveness during the COVID-19 pandemic.

Second, the rise in virtual tourism will continue after the pandemic. Popular destinations are moving to virtual tourism, allowing people to visit different attractions in a virtual way from their homes. Even after the outbreak is declared to be over, many people will be reluctant to travel and the recovery of the tourism industry is likely to be prolonged. The major effects of COVID-19 on the global economy include many businesses asking people to work part time or firing staff. Many people will be unable to afford to travel, and will chose domestic rather than international destinations. People may be nervous about traveling for a long time to come, and may prefer the experience offered by virtual tourism.

Third, travel options will be reduced in the future. Those airline companies that survive will cut their routes to small regional destinations which will result in fewer tourists requiring accommodation in these destinations, and many hotels closing down. There is likely to be more demand for longer-term stays to reduce the amount of travel and exposure at large airport hubs and on airplanes. There will be less mass tourism.

To sum up, in the future people will travel less which will mean lower demand for jet fuel.

Conclusions

It is too early to draw any conclusions about the impact of COVID-19 on international tourism. The effects of COVID-19 on tourism so far are not sufficient to allow firm conclusions since the impact of the virus will depend on how the pandemic evolves and how long it lasts. In the short run, the hospitality industry has been affected by the dramatic fall in flights, potential bankruptcy of airlines, hotel closures and cancelations of international events. Demand for jet fuel has decreased and is expected to continue to decrease in the second quarter of this year. In the long term, hospitality will be characterized by a change in consumer behavior and a rise in the use of technologies. We can expect less travel in the coming years which will mean lower consumption of jet fuel.

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Coronavirus Pandemic: Opportunities and Challenges for Energy and Low-carbon Transition

BY HONGBO DUAN, LIANBIAO CUI, LEI ZHU, AND XIAOBING ZHANG,*

The outbreak of COVID-19 has become the biggest crisis for the world since World War II and there is little doubt that the world has entered a global economic recession. Currently, there are more than 2,160,000 confirmed cases and more than 145,000 deaths across the world (JHU, 2020). The impact of this pandemic is dramatic: cities or countries are in lockdown, factories or stores are shut down, and bars and schools are closed. Coronavirus has led to an astonishing shutdown of economic activity, which would lower energy use, just as every recession did in the history. The 2008 financial crisis and the Great Recession that followed, had a profound effect on the energy sectors in the world, with decreasing the price of crude oil from about $150/bbl. to $35/bbl. in only a few months. Many economists expect that the COVID-19 pandemic would have a much larger effect on economic activity than the 2008 financial crisis. Therefore, it would be important to quantitatively investigate what this pandemic implies for the energy market and low-carbon transition for different regions as well as the whole world.

The typical approach, i.e., input–output (IO) models have been used widely to examine the effect of economic crisis or policies in response to the crisis. For instance, David et al. (1995) used a 10-sector input–output model of the UK to simulate the effects of a variety of policies issues connected with energy use and environmental impacts; and the short-term economic damage of the novel virus outbreak has also been estimated based on such methods (Duan et al., 2020). However, the IO models fail to consider the optimization or adjustments that the economy can reach by its own in response to the crisis. Further, the changes in dynamic interactions among various countries resulting from the crisis are beyond the capability of the I-O model framework. In contrast, computable general equilibrium (CGE) models have the benefits of enabling active adjustments by consumers, producers, or policy makers, and thus they have been used to generate insights into the impacts of economic crises (see, e.g., Burfisher, 2017; Cui et al., 2019). With regarding to the impact of the epidemic, it would be valuable to capture the roles of the supply chains and international trades, given the increasing trends of globalization (Mukhopadhyay and Thomassin, 2009). In this context, we use a dynamic version of the Global Trade Analysis Project (GTAP) model, in this paper, to see how the COVID-19 pandemic has affect the energy transition and carbon emissions across countries, where one is able to see the dynamic effect of this pandemic.

According to the severity of the COVID-19 pandemic, we re-divided the world of the GTAP model into 7 regions, i.e., China, the U.S., European Union (28 countries included, EU_28), Japan, South Korea (SKorea), the Middle East and North Africa (MES), and rest of world (ROW). We consider epidemic shocks for all the regions from both production and consumption sides, and three scenarios are designed, i.e., the Base-case scenario, the Conservative scenario and Pessimistic scenario. Based on the historical economic, energy and carbon emission data, we calibrate the GTAP model and project the critical indicators in 2020; then mpacts of the pandemic are measured by comparing the corresponding results under the epidemic shocks with the 2020 projections.

Under the Base-case scenario, the pandemic will damage the world economy by 2.1%; given the 2.9% projection without epidemic, the real GDP growth of 2020 could be 0.8%, which is largely in line with the estimate of the IHS Markit (Behravesh and Johnson, 2020). As for China and the US, the negative shocks to economy reach 2.6% and 2.4%, which are

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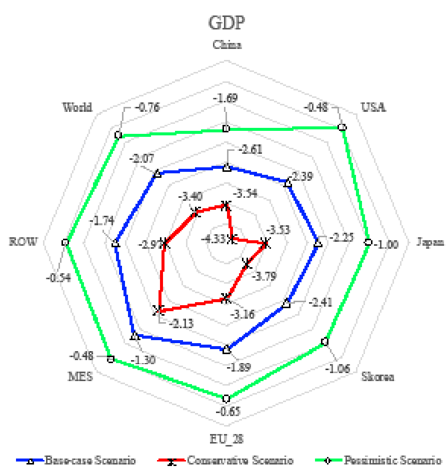
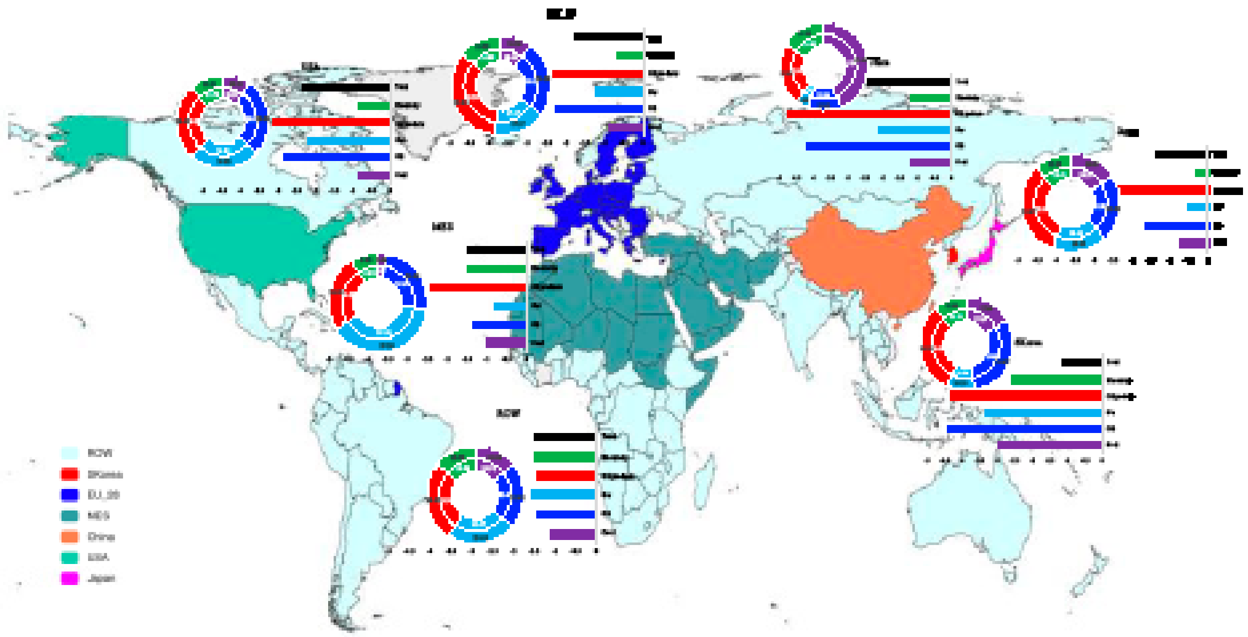


Figure 1. The impact of the COVID-19 pandemic on GDP across regions under different scenarios. These impacts are measured by percentage changes in GDP relative to the 2020 projections without epidemic.



Figures 2. Cross-regional shocks of the COVID-19 outbreak on energy consumption under the base case. The world map portrays the region divisions of this work, and the bars show the impacts of the outbreak on consumption of different energy technologies and the total (percentage changes relative to no outbreak case). The doughnut charts give the changes in energy structure without (the outside doughnut) and with (the inside doughnut) the shocks of the COVID-19 outbreak.

greatly consistent with the estimates under the global pandemic case of Bloomberg Economics (Orlik et al., 2020). Under the Pessimistic scenario, the damages for these two countries may further approach to 3.5% and 4.3%, respectively, relative to baselines of no virus outbreak. The pandemic are also major blows to the EU and Japan's economy, with the corresponding impacts to be -1.9% and -2.3%, respectively under the base case (Figure 1).

We find that the COVID-19 pandemic will lead to a significant reduction in energy consumption for all the regions/countries in 2020 (Figure 2), especially for China and the U.S, the corresponding declines could be 2.4% and 2.3%, respectively. The industries of oil and oil products are the most affected energy sectors in all the regions, particularly for China and South Korea, in which the consumption of oil and oil products may decrease by up to 4.7% and 4.3% in 2020 under the base case. When turning to the U.S. and the EU, the negative shocks of the epidemic to their consumption of oil decline to 3.1% and 2.3%, versus 2.8% and 2.3% for the consumption of and oil products. In contrast, the pandemic plays a limited role in energy structures, which implies that the influence of the epidemic on energy system should be short term. At the same time, we can observe a relatively weaker impact of the COVID-19 outbreak on renewables, as shown in Figure 2, and such negative effects in China and the US are only around 1%. However, it is still difficult to determine the epidemic is an opportunity or challenge for future energy transition from fossil fuels to renewable. On one hand, the relatively weaker impacts of the pandemic on renewables may due to their minor roles in current energy structure, and this could not

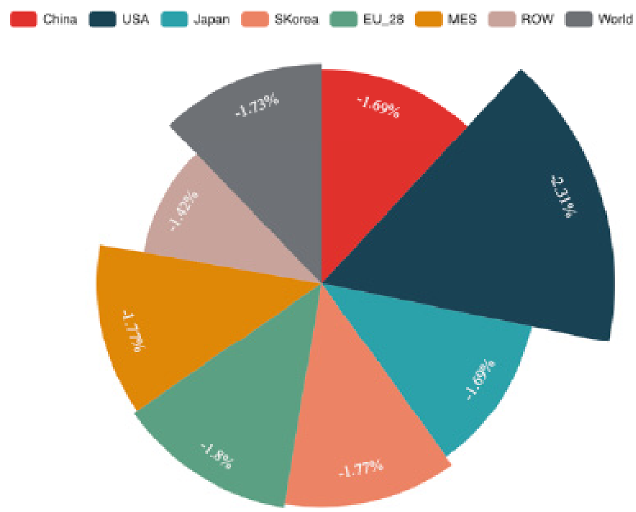


Figure 3. The impact of the COVID-19 outbreak on carbon emissions across regions under the Base-case scenario. These impacts are represented by percentage changes in carbon emissions relative to the 2020 projection.

lead to the conclusion that the epidemic is beneficial to the development of renewables. On the other hand, the big blows to global oil market do provide an opportunity for energy restructuring and the potential large-scale substitution of renewables for conventional energy.

The pandemic pauses the key of carbon emission increase. According to the chair of the Global Carbon Project, the world may usher in its first dip in carbon emissions since the 2008 financial crisis, with the expected fall to be over 5% (Stone, 2020). Actually, we are not so optimistic about the fall, despite the observable carbon emissions in China and the whole world do dramatically decrease in the first quarter, and this situation should be changed in the coming quarters. As depicted in Figure 3, the world's total carbon emissions in 2020 under the base case may reduce by 1.7%, versus 2.3% and 1.7% for the US and China. It is of little probability that the COVID-19 pandemic will benefit the worsening climate change situation, since the short-term drop in CO_2 emissions play a negligible role in the cumulative carbon contents and atmospheric CO_2 concentration; mostly importantly, the lessons from the 2008 financial crisis show that the emission will retaliatorily rebound after the drop. However, the carbon fall associated with the outbreak do enhance the causality between human activities and carbon emissions.

In conclusion, the coronavirus pandemic will trigger a recession to the global economy, and the economic downturn for the US and China are extremely stressed this year. The COVID-19 epidemic may not shock the current energy structure, but does have a dramatically negative impact on the total energy consumption at both global and country scales, especially for the consumption of oil and oil products. As a result, the increasing trend of the world's total carbon emissions in the past decade ceases. However, this short-term fall in CO_2 emissions associated with the pandemic may not change the increasingly strict situation of global warming, which relies on long-term decrease in carbon emissions and substantial low-carbon energy transition.

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IAEE/Affiliate Master Calendar of Events

(Note: All conferences are presented in English unless otherwise noted)

Date	Event, Event Title	Location	Supporting Organization(s)	Contact
2020				
Sept 22-23	BIEE Oxford 2020 Research Conference *Energy for a Net Zero Society: Achieving a Just Transition*	Oxford, U.K.	BIEE	Debbie Heywod http://www.biee.org/
Sept 30 - Oct. 2	5th Annual HAEE Symposium: *Energy Transition V: Global & Local Perspective*	Athens, Greece	HAEE	Spiros Papaefthimiou http://haee.gr/
Oct 9-10	3rd IAEE Southeast Europe Symposium *Delivering Responsible Infrastructure and Energy Solutions*	Tirana, Albania		Erlet Shaqe *https://see20.iaee.org/*
2021				
March 21-23	8th Latin American Energy Economics Conference	Bogota, Colombia.	ALADEE	Gerardo Rabinovich
July 4-7	43rd IAEE International Conference Energy Challenges at a Turning Point	Paris/France	FAEE/IAEE	Christophe Bonnery https://www.faee.fr/
August 29 – September 1	17th IAEE European Conference The Future of Global Energy Systems	Athens, Greece	HAEE/IAEE	Spiros Papaefthimiou *http://haee.gr/*
October 31 - November 3	38th USAEE/IAEE North American Conference *Energy Economics: Bringing Markets, Policy and Technology Together*	Austin, TX, USA	USAEE/IAEE	David Williams *http://www.usaee.org/usaee2020/*
2022				
July 25-28 Dates TBD	44th IAEE International Conference *Mapping the Global Energy Future: Voyage in Unchartered Territory*	Tokyo, Japan	IEEJ/IAEE	Yukari Yamashita *https://iaee2021.org/*
September 4-7	18th IAEE European Conference *The Global Energy Transition: Toward Decarbonization*	Milan, Italy	AIEE/IAEE	Carlo Di Primio https://www.aiee.it/
2023				
February 5-8	45th IAEE International Conference *Energy Market Transformation in a: Globalized World*	Saudi Arabia	SAEE/IAEE	Yaser Faquih
2024				
June 23-26	46th IAEE International Conference *Overcoming the Energy Challenge*	Izmir, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu *http://www.traee.org/*
2025				
May-June	47th IAEE International Conference *Forces of Change in Energy: Evolution, Disruption or Stability*	New Orleans	USAEE	David Williams *www.usaee.org*