The Outlook of Energy Markets in Q2 -2020

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To start with optimism..





The Many Faces of Climate Change

- Renewables (Solar, Wind, Hydro) versus 'Non Renewable'/ Fossil Energy (Crude Oil, Natural Gas)
- Coal is moderately discussed today as '*dominated*' by Natural Gas in a financial economics sense, at least in the developed countries
- Water is central, and vastly under-discussed
- Agriculture is crucial (Geman (2015)); '*To combat climate change, we can't ignore Agriculture*'- WSJ 11-10-2019
- The population of the planet is rarely discussed because it is a delicate matter, but obviously a crucial element

Risks in Energy/ Electricity/ Weather

- → One may want to start with some 'deep' thinking about randomness, before representing it as a probability $(\Omega, \mathscr{F}, \mathscr{F}_t, \mathbb{P})$
 - Nassim Taleb:
 - ' Fooled by Randomness', 2004
 - ' The Black Swan', Jan 2008
- → Besides the real/statistical probability measure which is our first encounter with randomness, we need to remember that there are many others that can be introduced: for instance, the 'risk-adjusted' probability measure(s) Q introduced in Finance to price random cash flows, and which has the merit of being unique if the market is complete
- → The market of Weather Derivatives is still incomplete; the electricity market was as well in the early 2000s, time when deregulation started all over the world. It is marching to completeness at this moment.

The Increasing Complexity of Asset Classes, Spot and Derivatives

- 1848 Futures on Corn (CME/Chicago Mercantile Exchange)
- 1877 Futures on Metals (London Metal Exchange)
- 1973 Options on Equities (Black-Scholes- Merton)
- 1990 Options on Crude Oil (Gibson & Schwartz)
- 1999 Futures on Electricity (Geman & Vasicek)
- 2000 Weather Derivatives (valuation still open), and now included in the more general class of 'Climate'
- 2017 Futures on Bitcoins on the CME (G., 2018)

Energy Markets are Connected

- Crude Oil can be replaced by Natural Gas, including in cars
- Natural Gas is transformed into Electricity in Combined Cycle Gas Turbines (CCGTs)
- Coal is transformed into Electricity in Thermal Plants
- In parallel, crude oil leads to oil refined products and petro chemistry, which are a different and gigantic market in its own right
- Coking coal is used to produce steel, itself used in turn in windmills: steel represents 71 to 79% of the total mass, and this steel gets used over time

Global Energy Consumption

Global energy consumption share by source, 1987-2017



Global Perspective on Energy in 2019

. US became in 2018 the first crude oil producer thanks to shale oil, passing Saudi Arabia and Russia, and remained so

For the first time, Russia has been negotiating with OPEC on production

. Vitol, a major trader in physical and financial oil, sees oil peak demand in 15 years, with natural gas replacing oil

. The US has also become a major producer of natural gas and started exporting

. LNG is becoming a key commodity in its own right, with less expensive smaller tankers available and offices open in Singapore by all oil majors. Note the importance of CCGT as a complement to renewables

. Coal is greatly receding, in the US in particular because of NG; still very much used in China and even more so in India

Cost of Renewable Energy

- The number of global annual CO2 emissions has risen from 2 in 1900 to 38 billion tonnes in 2019; per human being, it went from 1 tonne to 5
- Solar electricity costs went from 350 dollars per MW to \$70; offshore wind from 200 to 100 dollars
- Solar and Wind need to be backed up by batteries, hydroelectricity, hydrogen and Natural Gas
- A zero-carbon economy would require 4 to 5 times more electricity as the current consumption, all from non-carbon-emitting sources
- Hydrogen, mostly produced by electrolysis of electricity, will play an essential role and its consumption may jump 11-fold by 2050
- Hydrogen may be stored in a battery, making hydrogen and electricity interchangeable sources of energy

The Unique Complexity of Electricity Markets

• Electricity Markets involve 3 types of activity

- Generation, with generation price defined by the most expensive unit needed to meet demand and referred to as marginal cost of production. The process of submitting generation bids and the resulting price is called competitive pricing. The 'marginal cost of production' is paid to all bidders in order to avoid 'strategic bidding'. In general, the System Operator collects all the bids related to delivery the following day (Day-Ahead market)

- Transmission & Distribution are mostly under administration authorities

- Balancing and Reserve resources like Batteries, Combined Cycle Gas Turbines, hydro-pumping. These are also the subject of *auctions* and competitive bidding as they are key elements for the delivery of electricity at all times

Electricity Supply and Delivery



Electricity and Covid 19

- "Reliable power is critical for effective responses to COVID-19 and other diseases," states a report by Brookings Institution
- Roughly 790 million people lacked electricity access as of 2018, per a May 2020 report for the World Ban and WHO and other bodies
- That annual report on progress toward UN energy access goals notes that COVID-19 has "further accentuated the need for reliable, affordable access" in health care facilities
- Some places in Africa and Asia with access are often beset by unreliable or intermittent supplies.
- Reliable electricity is needed along the entire testing, treatment and eventual vaccination chain
- Power is needed for diagnostics on active infections, ventilator treatments, cleaning equipment and other key services in health care facilities, Brookings points out.
- Powering a cold chain will be critical to delivering a COVID-19 vaccine when it becomes available," they write



The Supply Curve in 2020 (New York ISO)



UK Electricity Prices 2015 - 2020



Energy trading conducted OTC, in RTOs, or commodity exchanges (e.g. NYMEX)

Cross-Commodity Hedging

Natural Gas for CCGT backup systems

• Weather Derivatives for Solar and Wind Generation

Wind Derivatives

- Structured mainly around wind speed and wind power in a given area
- E.g.: Wind Index based Futures, custom derivatives

Solar Derivatives

• Structured around total solar radiation in a given area

• EG. Solar Index based Futures, custom derivatives

Electricity Derivatives

• Structured around expected load and future generation

• Eg. Electricity Index based Futures, Reliability Options, PPAs

Energy Trading

Commodity Spot/ Physical Markets

- Supply and Demand prevailing at a given date t define the price; identifying them is not straightforward but quite rewarding, obviously
- Another key quantity is the available *inventory* at the date of analysis, worldwide or in a given region. This inventory has in impact both on the price and on the *price volatility* (see G -Nguyen , *Management Science*, 2005).
- Recent events in oil WTI showed the importance of this inventory which was the key reason for negative prices in March 2020 : Inventory was huge and market participants who held long positions in Futures contracts were prepared to sell them at a negative /very negative price in order to avoid the upcoming delivery of barrels of oil for which they could find no storage

Oil demand could decrease by 10 to 20mn bbls a day because of COV-19 and after. In March 2020, excess production took place because of the tensions US/Saudi Arabia/Russia: Conjunction of extreme events!



The Plunge of WTI Promptmonth in April 2020

WTI crude oil price per barrel

Futures contract for May delivery, April 20, 2020



Oil Prices 1984 to 2020 : Always Driven by Supply and Demand



U.S. WTI futures price, constant dollars, 1983–2020

BP profits down by 66% in Q1 2020 YOY; BP announces in June its plans to cut 10,000 jobs out of 70,000 because of the global oil demand and the company's shift towards renewable energy



Coal Mostly Receding Worldwide

- Australia: "Westpac Banking Corp. said it would exit the sector by 2030, leaving Australia and New Zealand Banking Group Ltd. as the last of the country's big four yet to commit to dropping the most polluting fuel."
- India: Electricity generation from coal India's primary source of electricity fell 32.3% to 1.91 billion units per day, with its contribution to overall electricity generation falling to 65.5%, compared with an average of over 73.7% last year."
- **U.S.:** "In April 2020, the largest round of coal mine layoffs in years swept through the Powder River Basin, the state's epicenter of coal production, with over 300 miners losing their jobs."
- UK : June 3, 2020 marked 2 months of coal-free electricity production

Coal is definitely receding in the US: NYMEX Coal Index vs Peabody and Arch Coal Share Prices



Corr(Nymex, Peabody) = 94.7%, Corr(Nymex, Arch) = 91.3%

New Coal Plants Still Built

Global coal-fired power project decisions and capacity changes



Additions, retirements and construction



New Coal Plants (continued)

- An IEA report of May 2020 showed why, absent tougher climate policies, coal will remain a huge player in global power markets despite its much publicized declines in the U.S. and Europe.
- Project approvals for new coal-fired power plants have plummeted over the past half-decade.
- But additions of new capacity are still outpacing plant closures, and IEA sees that continuing in the 2020–2023 period, driven largely by China and India.
- The big picture: "Net additions of coal-fired plants in 2019 rose for the first time in five years, driven by an uptick in newly commissioned plants in China and, to a lesser extent, in India," IEA notes.

Solar and Wind Advance despite Cov19

- The downward change of solar and onshore wind power costs mean they're now the cheapest source of new power development for at least two-thirds of the global population
- The annual survey of all-in costs for power projects underscores why analysts see COVID-19 slowing growth but not altering the fundamental trajectory of the technologies.
- The levelized cost of electricity for utility-scale solar and onshore wind projects has fallen another 4% and 9% since just the second-half of 2019.
- Wind has seen the steepest decline since 2015, they note, mainly due to a scaleup in turbine size, now averaging 4.1 megawatts, and priced at about \$0.7 million per megawatt for recently financed projects.
- The analysis measures the all-in costs of creating power, which means "development, construction and equipment, financing, operation & maintenance

The Numerous Risks in Commodity Markets

- Price Risk
 - high volatility and extreme moves in the spot and near-by markets
 - arbitrage gas / electricity
 - different prices in different countries for some commodities
- Volume Risk and Delivery Risk
 - changes in residential and commercial demand
 - Absence of sun with many solar panels supplying the market and missing electricity
 - Excess of the physical commodity and absence of appropriate storage (e.g.,oil)
- Credit Risk
 - Limits to be established with counterparties depending on their financial reliability
- FX Risk
 - Many currencies prevailing in the European energy market : euro, GBP, Norwegian krone, Danish krone, dollar
 - . Liquidity Risk in Forward/Futures Contracts

The Major Instruments in Commodity and Energy Markets

- Forward contracts came to existence centuries ago: a farmer A agreed at date 0 to deliver at date T one tonne of wheat at a price f(0,T); a 'speculator' B agreed to take delivery of the corn at date T and pay f(0,T). The farmer is 'hedging', i.e., taking away the randomness of his future revenues ; the speculator taking a risk in order to make an unsure profit
- In 1848, the Chicago Board of Trade came to existence and proposed Futures contracts, standardized forwards for monthly or quarterly maturities, and requiring the payment of *margin deposits* (to take a position), *margin calls* (to keep open a position after a day of loss).
- The amount of margin deposits may increase more than linearly for big positions: no positive 'homogeneity' of the risk from the Exchange perspective
- The choice of the margin deposits is crucial to the Exchange survival; they are usually between 3 and 12% of the contract value.
- On the CME, the margin deposit is 3% for crude oil, 44% for Bitcoins!

Forwards and Futures Contracts

- They constitute the vast majority of traded instruments in Commodity and Energy Markets
- Positions taken in Futures contracts, long or short, in an Exchange, require the payment of margin deposits at the start, margin calls to be paid if the Future contract has lost value between t – 1 day and date t
- With a Future contract, the global gain of a position is added every day to the trader's account: *marked to market*
- With a forward contract, all the gain is generated ay maturity T. For a long forward for instance,
- P&L (T) = f(0, T) + S(T)

Long Forward P&L at date T



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Theory of Storage
Keynes (1936), Kaldor (1939), Working (1949), Brennan (1958)
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Three fundamentals results:

a) The convenience yield accounts for the benefit that accrues to the holder of the physical commodity but not to the holder of the futures contract. It is represented as a dividend y and defined as y = b - c, where c is the storage cost and b the pure benefit

b) The volatility of the commodity spot price is high when inventory is low

c) The volatility of the Futures contract decreases with its maturity: 'Samuelson effect'

Note: Forward curves used to be most of the time in backwardation, the socalled "normal backwardation"; outdated since 2005 Three Dozens of Oil Tankers were parked off the California Coast in April 2020, acting as *floating storage*, since no storage facility was available on the ground



Spot-Forward Relationship

"Transferred" from economics into finance by Brennan (1958), Brennan and Schwartz (1985)

• The spot-forward relationship written *at date t* states that

 $f^{T}(t) = S(t) [1 + (r - y) (T - t)]$

where r and y are assumed constant over (t, T) - a reasonable assumption if the time period (t, T) is short

 Hence, the shape of the forward curve at date t is in a one-to-one mapping with the sign of (r – y). Backwardation if (r –y) <0, contango if (r –y) >0

Forward and Futures Prices on asset S, maturity T

- Theorem: Assuming an economy with no credit risk
- a) If interest rates are constant, f(t,T) = F(t,T)
- b) If interest rates are stochastic and Cov(S, int rates) = 0, f(t,T) = F(t,T); meaning that the margin calls' payment does not affect the price (see Geman, 2005)

Consequence 1 If S = equity, we cannot state that the equality holds since Corr is not zero, and in fact traders do play the difference Same thing if S = currency

Consequence 2 : If S =commodity, the equality holds and the forward and Future prices are not distinguishable under the assumption of no credit risk. In particular, the 'forward curve' – is built using the 'Future prices'

Steep Contango provides 'true' arbitrage opportunities: buy spot at date 0, borrow S(0), lease storage and sell a one-year Future contract. At maturity, the profit is F(0, T) – S(0) [1+ (r+ c)T] = 60 – 35 x1.12 >>0



WTI and Brent Forward Curve on Feb 4, 2015



Benefits from Carry Trade for Oil Companies in 2015

- During Q1 2015, BP, Royal Dutch Shell and Total had a record level of trading activity - related to an underlying of 4.9 mn barrels a day for Total and 6 mn for Shell and BP - and gained \$300 to 400 more than in a standard quarter
- The contango spread reached \$13 on the WTI and \$8 on the Brent over the quarter
- The storage cost is \$0.3 to 0.4 per month and per barrel on the ground and \$1.1 to 1.2 for floating storage
- BP and Shell spent \$1 to 2 in storage costs during the first quarter
- In April, the contango spread one year Future /first nearby declined to \$4 for the Brent and \$3.5 for the Brent

The Three Oil Forward Curves on April 21, 2020



The Current Natural Gas Markets

. Natural Gas has become a global market because of improved technology:

- Liquefaction facilities
- LNG tankers getting smaller, cheaper and more efficient

- LNG becoming a commodity in its own right, with Derivatives mostly traded out of Singapore

. BG Group and Shell had moved in 2014 their natural gas trading operations to Singapore

. The hedge funds Vitol, Glencore, Mercuria and Trafigura have trading desks there

NBP and HH Forward Curves on Aug 10, 2015



Nat Gas Henry Hub Forward Curve on 04/21/20 : Prices of Nat Gas followed the decline of Oil Prices



Swaps and Options

- A swap is a collection of forward contracts for different maturities but for the same price defined at date 0 by the 2 parties
- Swaps are extremely popular in Commodity markets as they allow consumers and producers to hedge their exposure at many points in time. as opposed to a single date: we consume continuously
- Options are of two types: physical or financial
- Physical and Real Options are written on the spot
- Financial options are written on Futures, with the maturity T1 of the future being often the maturity of the option plus one month in general;
- the price is given by the Black (1976) formula
- 'Physical' options are often written on the average price over a period:
 'Asian' options

The Black (1976) Formula

• Fisher Black (1976) observes that a gigantic volume of Futures contracts are traded on equity indexes or commodities



$$C^{Bl}(T) = Max(0, f^{T_1}(T) - k)$$

- He introduces options written on the forward/Future price of the stock or the commodity (equal since constant interest rates); in practice the forward contract's maturity is often one month after the option maturity T
- Keeping the same assumptions as in Black- Scholes, he derives the Black formula
 C(t) = exp [-r (T-t)] {f(t, T1) N(d1) k N(d2)}

The unprecedented Implied Volatility as those who had a long position in oil were prepared to pay any price to buy *put options* to cover their positions



Physical Assets in Energy

- They are the source of all revenues: oil fields, gas storage facilities, power plants, rights to explore; transmission lines in electricity; oil refineries
- It was in the context of energy that Dixit and Pindyck (1994) famously introduced the concept of 'real options', which was reused many times and allows to use results from option pricing as one way to provide a valuation for these assets *as long as one clearly identifies the different elements of the option*.
- Under the IPCC directives, many energy assets will become stranded and their costs for oil and gas companies will be enormous
- Between the geopolitical conflicts Russia/OPEC/US, the likely reduction of oil consumption and the directives of the IPCC, the challenges for oil companies – the old ones which used to be called the 'Seven Sisters' at the time when the oil markets came to existence, and the new ones like Aramco – are enormous.
- The Danish company Orsted, previously DONG Energy, has become a wind farm specialist; reinventing themselves for the big oil companies will be more challenging.
- As the first target for asset owners keen to decarbonise their portfolios, coal miners have performed disastrously over the past decade. Bloomberg's index of global coal miners, the largest of which are in China, has plunged 74 per cent from its peak in early 2011.

Pricing the Exchange Option (Margrabe, 1978)

It is the option to exchange at time T one asset S_2 for another asset S_1 Pay-off at time T = max (0, $S_1(T) - S_2(T)$)

This situation is very frequent in Commodities: exchanging coal for electricity (darkspread) or natural gas for electricity (sparkspread), crude oil for gasoline or jet fuel (crackspread)

Assuming a geometric Brownian motion for both asset ptices' dynamics, the pricing formula for C(0) is analogous to Black- Scholes, but with S₂ replacing the fixed strike price. Interest rates appear nowhere as the only thing which matters is the price of S₁ with respect to S₂(T) at date T Accordingly, the relevant volatility is the volatility Σ of the ratio of S_{1/}S₂

Valuation of Physical Assets in the Energy Industry: the case of a Combined Cycle Gas Turbine

->Scenario A

- Gas = 3.5 \$/MMbtu
- Power = 40 \$/MWh
- Heat Rate = 10 MMbtu/MWh
- Operate and profit = 40 3.5 x 10 = \$5
- -> Scenario B

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Gas = 4.5 $/MMbtu
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Do not operate

The ownership of the physical assets amounts to a portfolio of exchange options over the lifetime of the plant. Remarkably, the value at date 0 of these 'sparkspread' options does not depend on interest rates today and in the future. The use of Margrabe (1978) provides one valuation for these assets;

If the sparkspread options are traded, one can use their market price as another valuation approach

Managing a Hydropower Plant

Define U = total storage capacity (in Mwh)
 B = daily maximal production
 S(t) = spot price of electricity

• Total revenues given by the integral of {price S(t). q(t)}

where an admissible policy $q = (q_t)$ is subject to the constraints

 $0 \le c_{j_t} \le B$

and

the goal is to maximize the revenues over a given hydrological year

Commodity- Related References

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