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Copper Is The New Green

A New Metal Supercycle

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Recent Commodity Boom:

Confluence of Fortuitous Events

2021 has so far delivered a phenomenal ride for commodity investors. Crude oil prices have staged a strong recovery to above pre-pandemic levels. Agriculture and industrial metal prices have soared to the highest levels in nearly a decade.[1]

Bullish economists and strategists have responded to this by declaring that the long-suffering commodity markets may be just warming up, with the recent revival marking the first innings of a new commodity supercycle.

While we do have a long-term bullish outlook on select commodity assets, specifically industrial metals levered to decarbonization investments – this topic is explored in-depth in the following sections – we caution a simple extrapolation of the recent commodity boom into a prolonged "supercycle."

In fact, we believe the recent commodity boom is really a confluence of fortuitous events. On the surface, the recent commodities rally does appear to be a synchronized macro story of pent-up demand coupled with economic recovery. Indeed, all key commodity futures markets are in backwardation.[2] Yet, a more in-depth look into the supply and demand dynamics reveals that recent market conditions have been driven mainly by fundamentals specific to each commodity asset.

For example, crude oil prices recently reached their highest levels since January 2020 despite the news of delayed reopening in Europe, India, and Latin American due to rising COVID-19 cases. Undoubtedly, this is supported by favorable conditions on the supply side, in particular the OPEC+'s decision to pursue a tight oil market strategy, which in turn is influenced by the capex discipline exhibited by shale producers.

Agricultural commodities have been affected by their own unique market forces. Prices of corn, for example, soared an impressive 80% over the past eight months, driven by strong and sustained demand for feed consumption from China as it rebuilds its pork stock following the swine fever outbreak in 2019.

The dominance of micro over macro forces has been particularly pronounced within industrial metals. Iron ore, for example, has seen a remarkable 70% gain in prices since January 2020, outperforming most of its peers.[3] This was driven by a combination of supply tightness in the first half of the year (due to production disruptions in Brazil and Australia) as well as robust demand (construction sites were among the few areas that remained open throughout the lockdowns). Going forward, however, iron ore may be heading down a path of structurally weaker fundamentals. The recent new environmental policies from China targeting highly polluting steel mills likely signal a structural turning point in its consumption trajectory over the long term. On the supply side, a sustained recovery in production from Brazil following two years of persistent underperformance should further weigh on prices going forward. The trends in the prices of iron ore – both the remarkable rise in 2020 as well as recent sudden pause in momentum – have all been driven by asset-specific forces, the effects of which do not translate to other metals.

In short, the key drivers behind the recent commodity boom have been overwhelmingly sector- and asset-specific micro factors that are unlikely to launch new long-term developments in the commodity markets.

Are we suggesting that some may have read too much into this recent commodity boom? Yes, we are.

So, does that mean we disagree with the call for a new commodity supercycle? Actually, we do agree. However, we think this new cycle is going to be less agnostic and more targeted.

[1] Source: Bloomberg. Data as of 3/26/2021.
[2] Despite the well-known "forecasting theory" that the slope of the futures curve (i.e., contango or backwardation) provides predictive information of future spot prices, academic studies on the efficacy of futures prices' ability to forecast spot prices have reported mixed, inconclusive results. Source: Reichsfeld, David A, & Roache, Shaun K. (2011). Do Commodity Futures Help Forecast Spot Prices? IMF Working Paper.
[3] Source: Bloomberg. Data as of 3/26/2021.

Clearly, it is critical to identify the key drivers behind the price of an asset, in the past, at present, and – we can postulate – in the future. On a relative basis, it is much easier, once we have visibility into the drivers behind recent changes, to assess whether the current market or economic condition is transient. It is however much more difficult to make the call on whether we are at a turning point towards a multi-decade structural shift.

The point is that we consider the linkage between the recent commodity boom and a potential new commodity supercycle – if one were to happen – essentially nonexistent.

A More Selective Supercycle

What is a supercycle?

When an unexpected increase in demand happens, a potential lag in supply would create upward price pressure until eventually adequate supply becomes available. For example, in the case of metals, building a new mine requires not only time but also resources (i.e. the willingness to invest towards building the mine).

A supercycle occurs when demand growth is so persistent, so intense, and so relentless that it takes multiple years or even decades until supply catches up or demand moderates, thus fueling a long-term trend of rising asset prices.

The global economy is in the early stages of a significant recovery. Increasing economic activity is generally associated with a rise in aggregate commodity demand. Such demand growth in the early stages of a market cycle does have the potential of creating a short-term commodity price boom. To create a supercycle, we need more. In our view, the type of commodity consumption increase that is powerful enough to sustain a multi-year or multi-decade race with production that is trying hard to catch up can only come from a significant structural development.

Could the global decarbonization movement be that development?

In our paper published in August 2020, we wrote about a new era forming in the financial wreckage wrought by the pandemic, and that "the new era has a tint of green."[4] The goal of achieving net zero global greenhouse gas emissions by 2050 has shifted from a somewhat theoretical aspiration to a genuine movement. Decarbonization, in our view, is one of the most dominant themes in terms of shaping economic and societal changes over the next few decades. Within the decarbonization movement, there appears be overwhelming support for massive electrification as the most probable and realistic pathway to achieving net zero carbon emissions by 2050.

Significant future investments towards decarbonization and massive electrification may be powerful enough to unleash a new commodity supercycle.

Unlike the broad-based boom across the commodity complex in the prior supercycle of the 2000s, we believe this new supercycle will be more selective, focusing specifically on industrial metals levered to green electrification investments. Indeed, prices of copper, aluminum, and nickel have soared in recent months. Yet, so have most other commodity assets.

Based on our studies of the previous metal supercycles, there needs to be at least one of the following key ingredients in consumption change for a commodity boom to evolve into a multi-decade supercycle: *new applications for which the materials are needed* or *an increase in material intensity (consumption per GDP)*.[5]

Since the late 19th century, metal prices have experienced four supercycles.[6] The first arrived in the late 1890s, as industrialization led to rapid economic

[4] It is Easy Being Green. Rockefeller Capital Management. 8/20/2020.
[5] Material (in this case, metal) intensity of the economy is the ratio of domestic material consumption to GDP at constant prices. Source: The United Nations.
[6] Erten, B., & Antonio Ocampo, J. (2021). The future of commodity prices and the pandemic-driven global recession: Evidence from 150 years of data. World development, vol.137. The study identifies supercycles by first deflating nominal commodity prices since 1865 using the manufacturing unit value index to capture real price changes, and then decomposing real commodity prices using the asymmetric band-pass filter into several cyclical components: long-term trend, supercycle, and short-term cycle.

growth in the US and Western Europe. The second, which took place from the late 1920s to the 1940s, was the result of global rearmament. The third and the longest began in the early years after WWII, fueled by the post-war reconstruction of Europe and later the massive economic expansion of Japan, and eventually faded away in the 1990s. The fourth and the most recent metal supercycle in the 2000s was closely linked to the meteoric economic rise of China after joining the WTO in the early 2000s.

Industrialization and urbanization have been the key drivers of all four previous supercycles. This is not a coincidence. The industrialization of the US economy that began in the 1880s involved technological advances that led to new applications of metals. The construction of railroads, for example, was a major force in the expansion of the US iron and steel industry. More recently, the rapid urbanization of China in the 2000s and early 2010s unleashed the pent-up demand of over one billion people who wanted an apartment, a car, appliances, and an improved lifestyle. This led to a surge in the country's intensity of metal use, which was critical to increasing China's annual metal consumption to around 50% of the world's total, from 15-20% in 2000.[7]

The acceleration and broadening of the green electrification agenda includes widespread adoption of electric vehicles ("EVs") and the surrounding charging infrastructure, restructuring the electric power sector and increasing the utilization of renewable energy (e.g., solar and wind), electrification of buildings, etc. The list goes on. Every one of these developments will either create new applications for metals, increase intensity of metal use, or both. And they add up.

Commodity assets are notoriously difficult to price. Forecasting how the commodity markets will perform over the next decade and beyond is certainly not an easy task. Yet, as we assess – in the following sections – the potential magnitude of demand for industrial metals that global decarbonization and massive electrification efforts will bring, we are inclined to believe that a new metal supercycle – led by synchronized global decarbonization efforts – is underway.

Among the industrial metals levered to decarbonization and clean energy initiatives, copper, in our view, has the most bullish long-term story.

Relative to other metals, copper has the most immediate ties to global decarbonization efforts. It is a vital part of green infrastructure and massive decarbonization. Demand from electric vehicles, charging stations, renewable power generation, grid infrastructure, battery storage – just to name a few – currently accounts for about 20% of global copper consumption. This percentage, in our view, is poised to grow significantly and on a continual basis. As the global economy begins to recover from the economic destruction wrought by the pandemic, more and more resources from both the public and the private sector will go to global decarbonization in an effort to build back better.

We also have a favorable long-term view on aluminum, which is also levered to the global decarbonization movement. Importantly, aluminum is a potential substitute for copper in some applications such as power grids and stands to benefit if copper experiences sustained supply deficits.

From Hay to Gas, and Electricity

If the world is committed to achieving net zero carbon emissions by 2050, the electrification of transportation, aka widespread conversion from conventional gasoline-fueled vehicles to battery electric vehicles, objectively and definitively must happen.

There is growing evidence that the prospect of a fully electric fleet on the road by 2050, or even sooner, has shifted from a previously theoretical concept to an increasingly probable reality, backed by commitments by policymakers across major economies.

[7] Source: ICSG, USGS, WoodMac, Bloomberg Intelligence. 3/21/2021.

The European Union has been at the forefront of combating climate change. Although the Union's carbon emissions have declined by nearly 25% over the past three decades, thanks to the remarkable rise in the utilization of solar and wind energy in power generation, carbon emissions from transportation have been steadily on the rise in recent years.[8] The EU aims to have at least 30 million EVs on the road by 2030, as it seeks to steer its member countries away from fossil-fueled transport.[9]

China recently committed to peak emissions by 2030 and net zero by 2060, surprising many in the international community.[10] Importantly, although China generates the largest share of greenhouse gas emissions in the world (26%) – double the amount emitted by the US – the bulk of those emissions stem from coal burning and highly polluting industrial activity. On the transportation front, China actually owns nearly half of the global stock of EVs; its carbon emissions from transportation are half the amount relative to the US.[11] The adoption of EVs, in our view, is motivated by, among several factors, China's goal of becoming the global leader in innovative green technologies, a dominant industry in the decades to come.

Compared to Europe and China, the US is behind on the adoption of electric vehicles. As a result, its progress on this front should deliver greater incremental benefits. The transportation sector accounts for the country's largest share of carbon emissions (28%).[12] With the US-China technological race rapidly intensifying, active engagement by the US in decarbonization and energy transition efforts, in our view, present immense economic opportunities and geopolitical advantages. The US recently formally rejoined the Paris Climate Agreement.[13] The Biden administration is now in talks with US automakers about a full transition to sales of electric-only vehicles by 2035.[14]

Copper is a cornerstone of the EV revolution.

As the best non-precious metal conductor of heat and electricity, copper is used in every major EV component, from the motor to the inverter to the battery and the wiring. There are no viable alternatives to copper.[15]

As a result, compared to a conventional internal combustion engine ("ICE") passenger car, an equivalently sized battery-powered electric vehicle uses approximately *four times* the amount copper (83kg versus 23kg).[16]

Intuitively, a global conversion to electric vehicles will permanently change the copper market with regards to demand growth driven by both new applications and increasing intensity. Exactly to what extent will widespread adoption of EVs impact the future demand of copper?

Currently, around the world there are approximately 800 million vehicles on the road. The percentage of those that are electric is a rounding error. A complete conversion to EVs, based on the copper usage requirement today ($60kg per car), translates into 48 million tons.[17] As a reference point, the total global copper mine production has been flat at around 20 million (metric) tons in the past five years.[18] Total refined copper production – generally higher due to the inclusion of recycled copper, was 24 million tons in both 2019 and 2020.[19]

The significant potential of demand growth makes copper our most bullish fundamental story.

It seems inevitable that widespread EV adoption will spark a multi-decade copper supply shortage and

[8] European Environment Agency Greenhouse Gas Emissions Report 2020.
[9] Source: Reuters. 12/4/2020.
[10] Source: Bloomberg. 9/22/2020.
[11] Source: World Resources Institute. Greenhouse Gas Emissions by Countries and Sectors (2018)
[12] Source: US Environmental Protection Agency. US Greenhouse Gas Emissions by Sector (2018)
[13] Source: The New York Times. 2/19/2021.
[14] Source: CNN. 1/29/2021.
[15] Copper Alliance, Copper Droves Electric Vehicles.
[16] Source: The World Copper Factbook 2020.
[17] Our estimate assumes all the vehicles are passenger cars, which is a conservative estimate. The differential in the usage of copper increases with the size of the vehicle.
[18] Source: The World Copper Factbook 2020.
[19] Source: The World Copper Factbook 2020.

correspondingly a sustained increase in copper prices. If we assume a full EV conversion over the next three decades, or at a rate of 27 million cars per year, copper demand, in theory, will rise 7-8% per year for thirty years. This does not consider other variables such as global population growth and potential increases in car ownership particularly in emerging economies. We do acknowledge that this growth rate is an aggressive estimate. First, EV conversion will not occur at a linear rate starting from today given the current EV production capacity, which, however, is expanding at an exponential rate.

Realistically, we expect the path to widespread EV adoption to span decades. During the last major shift in transportation – sparked by the invention of the combustion engine – it took the automobile nearly 50 years to dislodge horses from wagons on the streets across the US.

Although this new transportation evolution will likely also take place over decades, with the conversions potentially backloaded, the scale of this movement, in our view, is sufficient to initiate a new metal supercycle.

The production growth rate of copper has historically been fairly steady at around 2%. We believe, even at a rate of three million EV conversions per year, which translates into an increase in global copper demand at the annual rate of 1%, the demand and supply imbalance on a continued basis has the potential of unleashing a material effect on copper market conditions.[20]

Our hypothesis is supported by what took place during the most recent commodity supercycle of the 2000s. Copper prices soared, driven by increased demand for consumption from emerging economies that were undergoing rapid urbanization. Over this period, global copper production increased on average 2.6% per year, while the annual growth rate in global copper consumption averaged 3.4% – a delta of merely 0.8%.[21]

Creating the infrastructure around EV, such as charging stations, generates further demand for copper. One of the greatest pushbacks or hesitancies from the consumer's perspective is the lack of available charging stations on the road. Investments from policymakers and the private sector into EV infrastructure have accelerated, with significant capex growth potential – and demand for copper – over the long term.

As the EV industry continues to mature, gaining market share at the expense of conventional vehicles, the business ecosystem built around conventional gasoline-powered vehicles will need to adjust in response. It is conceivable that there may be an inflection point, at which EV conversion begins to accelerate rapidly. As it gets harder and harder to find a gas station on the road, owners of conventional gasoline-powered cars may decide that it is finally time to let go.

This new transportation revolution may end up happening a lot faster than the last major shift in transportation more than a century ago.

Massive Electrification Equals Long Wires and Battery Storage

Achieving the goal of net zero carbon emissions by 2050 requires simultaneous actions on multiple fronts.

The genesis of the push for global EV adoption or more broadly, the overall massive electrification initiative, is to power the global economy from carbon free sources, thus reducing greenhouse gas emissions.

The most essential part of the decarbonization movement is achieving clean electricity. This requires a significant increase in the share of low-carbon energy, e.g., wind and solar, in electricity generation, and, correspondingly, minimization of the share of fossil fuels.

In 2019, 84% of the electricity consumed in the world was generated by burning oil (33%), coal (27%), and natural gas (24%). Only 5% of the electricity

[20] As the capacity of EV production increases and the pace of conversion picks up, the imbalance is likely to increase from the initial level of 1%.

[21] United States Geological Survey

consumption was from renewables.[22] This paints a rather depressing picture of the how far we are from achieving the goal of net zero emissions. In fact, even the energy mix in the European Union, which has been leading the global efforts against climate change, still includes more than 20% of coal and natural gas in its electricity mix.[23]

What is the root cause for our dependency on fossil fuel in electricity power generation? In most parts of the world today, renewable energy has become the lowest-cost source of power generation (subsidy-free).[24]

The issue traces back to our power grids, which transmit power generated at a variety of locations and distribute it to end users, e.g., homes, buildings, factories, etc. In most countries, however, the power grids were built decades ago and were designed primarily for transmitting electricity from large, centralized power plants, most of which use carbon-intensive sources such as coal, oil, and natural gas. Such outdated design along with the aged supporting infrastructure have become increasingly ineffective to accommodate the transmission and distribution of electricity generated by renewable energy.

For example, due to the nature of wind and solar power, power plants are usually located where the resource is the strongest, which could be in the middle of the ocean or an isolated desert. When electric power is sent over very long distances from one part of a country to another, there is significant voltage drop along the traditional transmission lines. In addition, the availability of wind and power resources often varies significantly across a country. In the absence of a centralized power grid system, regions that have large electricity demand and do not have nuclear power plants or access to an abundant amount of wind/solar resource will inevitably use fossil fuels for power generation.

Given the inherent variability of wind and solar sources, which is a function of weather conditions, power grids must also be able to withstand a large infusion of energy without overheating or breaking down. On the other hand, the resilience of the power grids and the supporting infrastructure is arguably even more critical when there is a lack of renewable energy being generated. Without relying on fossil fuel plants as a backup, the power grids need to integrate battery energy storage (with sufficiently high storage capacity) into the system.

Collectively, these considerations call for significant infrastructure investments towards updating the existing outdated power grids to improve transmission efficiency as well as resilience (e.g., by building and integrating battery energy storage). Furthermore, a significant increase of the share of wind and solar power in our electricity generation naturally calls for building more windmills and solar farms, and correspondingly new grid lines. Note that while the costs for wind and solar energy plummeted significantly in recent years, they are projected to decline even further with improved operational efficiency, design, and locations. Similarly, technological advances have also driven down the costs of batteries, making the integration of battery energy storage an economically (not to mention environmentally) more attractive option compared to using backup fossil fuel plants. While it may appear that we are a long way from achieving clean electricity in the near future, there is a clear path forward.

Copper, once again, is the cornerstone of the restructuring of our power systems. It is a vital part of the electric power infrastructure, from grids to battery energy storage.

Note that, as we mentioned earlier, copper is an excellent conductor of heat and electricity and is highly resistant to corrosion. With that said, aluminum is a viable alternative to copper, with significant cost and weight benefits. The conductivity of copper wires, however, is twice that of aluminum wires with equal thickness.

[22] bp. Statistical Review of World Energy 2020.
[23] IEA. Q1 2020.
[24] IRENA Global Renewables Outlook, 2020

Ultimately, the clean electricity initiative will generate a lasting increase in demand for copper (and potentially aluminum) over the coming decades. According to an estimate by Bloomberg, 30 million miles of new power grid will need to be built by 2050 to reach the goal of clean electricity power generation. The total consumption of copper is likely to be substantially higher, given the additional metal needed for upgrading the existing power grids as well as constructing sufficient battery energy storage for the power sector across the globe.

Supply Disruption Is Transient, Decarbonization Efforts Aren't

Much of the rally of copper prices in the recent months has been attributed to the production disruptions in Chile and Peru – the top two copper producers in the world – as a result of lockdown measures. In addition, conservative capital allocation decisions by copper producers across continents have raised concerns over the supply tightness further down the line. Production disruption coupled with demand recovery amid improving global economic activity can potentially be a valid argument for being bullish on copper in the near term, if one believes that the dynamics will persist and are not yet fully captured in the market prices. That, however, is really not the point of the story that we are focusing on. Indeed, the capital allocation decisions, reduced capex in ramping production, in particular, are expected to have some lasting effects on supply tightness for some time. Fundamentally, however, such shocks from the supply side are transient in nature. Intuitively, such supply-side imbalance is self-solving. We have fairly high confidence that production will eventually begin to pick up if the copper rally continues.

Our story about a new supercycle of industrial metals levered to decarbonization efforts is motivated by our expectation that metals such as copper will experience a structural change in demand growth, a change so strong and so persistent that that it ultimately creates a supply deficit lasting over multiple decades.

We believe that the extent of the structural demand growth that we expect over the coming years has not been fully recognized by the market. The recent temporary retreat in copper prices driven by concerns over China's credit tightening and potential future demand weakness suggests that the copper market remains still very much focused on the supply and demand dynamics in the near term. This is also evidenced by copper's backwardated futures market.

The story that we are focusing on in this paper is about what happens over the next five, ten, twenty, and thirty years. Our estimated future increase in demand for copper has a high probability of creating a supply and demand imbalance that persists for decades. A globally synchronized fight against climate change has the potential of initiating changes that we normally would not think possible. The decarbonization movement, at its core, is a war against rising global temperatures. For the first time, the major global powers collectively recognize greenhouse gas emissions as a common enemy that poses existential risk to humanity. It has taken many years; nonetheless, we got there eventually. And the clock is ticking.

Vast amounts of materials and resources were consumed at the direction of country leaders during WWII, which touched nearly corner of the world. More recently, unprecedented fiscal spending has occurred in response to the pandemic – amounts unimaginable prior to the crisis. The amount of resources that we have available today is substantially greater than we did nearly a century ago. The fight against climate change is going to last much longer than the length of the current pandemic, with potential casualties greater that what we have witnessed recently. Rising global temperatures pose a greater threat to humanity than any war our society has ever encountered.

The one positive element is that countries around the world have finally put aside our differences to face, as one, our common enemy.

Given this context, if consuming more copper at what most would consider elevated prices is what it takes to significantly increase our odds of winning this war, we'd like to think that it'd be an easy decision.

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