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Taming the Hydra: Funding the Lithium Ion Supply Chain in an Era of Unprecedented Volatility

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Abstract

The lithium ion supply chain is set to grow in both size and importance over the coming decade due to government-led efforts to decarbonize economies and declining costs of lithium ion batteries used in electronics and transportation. With forecasts of demand for lithium chemicals alone forecast to grow by three times later this decade, at least \$10B USD is needed to flow into the upstream supply chain to ensure an efficient and timely build-out. Significant additional capital is needed for other portions of the supply chain such as other raw materials, cathode or anode production, and battery cell manufacturing. Recent exogenous shocks such as the US-China trade war and coronavirus disease 2019 (COVID-19) pandemic have made securing adequate capital for the supply chain a difficult challenge. Without the steady stream of funding for new mine and chemical conversion capacity, widespread adoption of electric vehicles (EVs) could be put at risk. This paper discusses the current structure of the lithium ion supply chain with a focus on raw material production and the need for and challenges associated with securing adequate capital in an industry that has, to date, not experienced such a robust growth profile.

Keywords: lithium, capital, capital allocation, investment, lithium ion, supply chain

1. Introduction

In Greek mythology, the hydra was a nine-headed monster that terrorized the local populace. When one of the hydra's heads was cut off, two grew back in its place. This evolving menace was ultimately killed by Heracles and his nephew Iolaus with Heracles severing each head and Iolaus cauterizing the wound, preventing the regrowth of additional heads.

In modern times, a problem described as a hydra is one which is multifaceted or continually evolving. The lithium ion supply chain has some similarities with the hydra in that there are multiple businesses (mining, refining, cathode and anode production, battery cell and pack production) which are all different in terms of operational complexity and funding needs. **Figure 1** demonstrates a high-level overview of the lithium supply chain.

Despite the complexity, the lithium ion supply chain is positioned for a strong growth based on the twin tailwinds of government requirements for decarbonization and falling lithium ion battery costs in the next decade. By the author's estimates, should electric vehicles (EVs) become 10% of global autosales later this decade, this would require three times more lithium than is currently produced

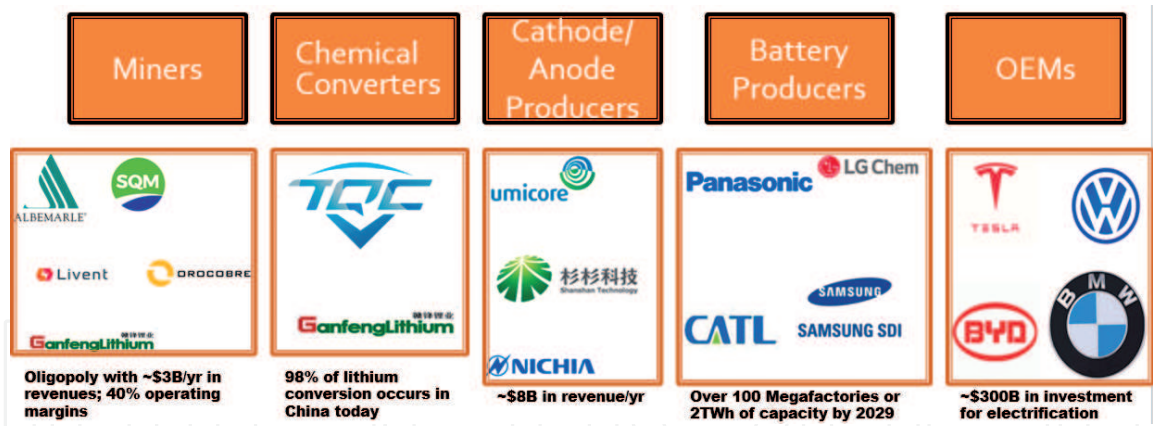


Figure 1.

A high level view of the lithium supply chain today. Source: House Mountain Partners, LLC.

globally today, given certain assumptions on battery size in kilowatt-hours (kWh) and battery chemistry. This tripling of demand ignores the growth in other sectors that use lithium such as pharmaceuticals or glass and ceramics.

However, the trajectory of this rather sunny scenario has recently been called into question. The US-China trade war and simultaneous supply and demand shock of coronavirus disease 2019 (COVID-19) are forcing investors and companies—traditional sources of capital to feed the growth of the supply chain—to pause and scrutinize capital allocation decisions. The entire industry is just beginning to understand the implications of these shocks, and this evolution can cause capital commitments to freeze or vanish altogether. In the past year alone, major lithium producers Albemarle, Sociedad Química y Minera de Chile (SQM), Livent, Ganfeng Lithium, and Tianqi Lithium (known collectively as “the Big Five” as they produce the majority of global lithium supply) have halted or slowed production expansion plans due to low lithium prices and softer than expected demand. The macroshocks referred to above have also hurt the development-stage mining companies with high-profile failures becoming more frequent.

With its multiple subsectors (mining, refining, cathode and anode production, and separator production, battery production, automotive), the comparison of the lithium ion supply chain to the hydra is apt.

The winds of change have dawned on one head of the hydra—the global automotive business. Mary Barra, chief executive officer (CEO) of General Motors (GM) referred to this volatility, stating in 2017:

I have no doubt that the automotive industry will change more in the next five to 10 years than it has in the last 50. The convergence of connectivity, vehicle electrification, and evolving customer needs demand new solutions [1].

In an environment where equity investors view results on a quarterly basis, lithium company CEOs and chief financial officers (CFOs) are under immense pressure to deliver immediate returns to shareholders while at the same time ensuring that they maintain or increase market share by investing in the future and managing a lag in recouping those costs in the future.

This paper discusses the upstream lithium ion supply chain through the lens of capital allocation. The various subsectors of the business can be thought of as various heads of the ancient hydra—unwieldy, growing, and hungry (in this case for financial capital). I will discuss why governments around the world are intent on decarbonizing the transport sector, the importance of investment during different phases of the capital cycle, and the traditional challenges associated with capital allocation.

Trade war dynamics and COVID-19 have shocked the global economy and given investors pause in terms of how, when, and where to invest. The lithium ion supply chain is not immune here, but nobody disputes that in 10 years' time, this supply chain will be larger and more critical to the global economy than it is today. What is debatable is what the supply chain will look like and how to structure and deploy the enormous sums necessary for growth.

2. Why electrify?

The push for the electrification of transport via increased EV penetration centers on government goals to decarbonize the sector and mitigate the effects of climate change. At least 14 countries have announced their intention to ban the diesel engine by or before 2040 with numerous cities across the globe making similar announcements. The transport sector is responsible for 23% carbon dioxide (CO₂) emissions and over 25% of oil demand according to the World Resources Institute (WRI) [2] and the US Energy Information Administration (EIA) [3]. The European Union (EU) has been a leader in the fight against automotive emissions, thanks in part to the Dieselgate scandal and concerns about climate change. The true global leader in pushing vehicle electrification to the fore, however, is China.

It is widely accepted among Chinese authorities that a key to continued growth of the domestic economy is through investment along multiple parts of next-generation supply chains, effectively owning the intellectual property that emerges from it. Programs such as Made in China 2025 have laid bare the desire on the part of the Chinese state for deeper integration into and dominance of next-generation supply chains. Made in China 2025 is essentially a blueprint for next-generation industrial dominance where China aims to control at least 70% of the global production of industries such as new energy vehicles, high-end microchips, renewable energy infrastructure, robots, and advanced medical technology with slightly less ambitious goals for other industries [4]. This push has met with predictable pushback from other competitor countries such as the United States, but China's intentions and goals are laid bare for all to see.

A second tailwind for electrification in the future concerns the lithium ion battery itself and its cost trajectory. Bloomberg New Energy Finance claims that battery prices in terms of \$ per kWh have fallen by 87% since 2010 [5]. While Moore's law is not applicable with lithium ion batteries, these devices have undoubtedly benefitted from the technology-driven cost deflation which emanates from a mix of scaled production and technological advances in increased energy density. Lithium's light weight and capacity to store energy dictate that it is the material of choice for energy storage and mobility for at least the next decade despite other competing storage technologies. Lithium ion batteries have been commercially used for 30 years. That mix of a safety record, coupled with light weight and capacity to store a charge, places it at the top of the battery metal pyramid.

It is important to realize that metrics such as costs and demand growth rates will not move in a linear fashion as battery technology continues to improve. Though COVID-19 has caused a re-think of demand numbers across the supply chain, the general trend of double-digit demand growth remains intact over the long term. One of the challenges for automotive companies concerns the rapidly evolving battery technology and which will be the ultimate winner. There are at least six major types of lithium ion battery chemistries alone, and building a multibillion-dollar business around one or two of these chemistries is a decision many in corporate board rooms wrangle with as we speak. It is generally agreed upon in the industry that there will not be a single-cell format or lithium ion

chemistry that ultimately wins, as different applications have different power and energy density requirements.

Regardless of the lithium ion chemistry of choice, the upstream portion of the lithium ion supply chain—raw materials—will need to grow rather dramatically in size in order to meet even base case assumptions for EV penetration in the coming years. This presents both an opportunity and a challenge as there are multiple lithium ion battery chemistries, multiple cell formats, and multiple battery sizes measured kilograms per kilowatt-hours. As an example, assuming a 10% EV sales penetration rate, the demand for lithium will increase by 3×, cobalt will increase by 2.5× based on author estimates. These numbers could change slightly based on changes in any of the factors previously listed, but the fact remains—we are going to need substantial amounts of additional raw material supply to electrify the global transport sector.

Similar demands will be placed on downstream portions of the supply chain with cathode production across different chemistries expected to grow strongly, cell and battery manufacturing growth all but obvious, and original equipment manufacturers (OEMs) committing reportedly \$300B in electrification efforts across the next decade [6]. Each piece of the supply chain here must coordinate its growth with the other pieces (or heads of the hydra) in order to ensure optimal capital allocation and prevent waste and undue excess production capacity.

3. Supply chain growth and regionalization

For the lithium ion supply chain to grow sustainably as mentioned above, there is an assumption that needs to be made and several challenges that need to be navigated.

The assumption in question is that consumer demand for EVs and demand from fleets such as Amazon and car rental companies will materialize on a time frame suitable to investors and companies alike. This narrative still appears intact despite a COVID-19-led demand implosion and total cost of ownership (TCO) EV costs that are still higher than that of internal combustion engine (ICE)-powered cars. As of April 2020, it is still unclear what the effects of COVID-19 will be on consumer sentiment toward EVs, but some anecdotal evidence suggests that once price parity is achieved coupled with intangible benefits of cleaner air, the demand for EVs should recover [7]. This assumption bears careful scrutiny as the effects of COVID-19 continue to evolve. It would be fair to say that EV demand in the current environment will certainly be delayed, but not denied.

The benefits of companies such as FedEx or Amazon decarbonizing their fleets speak for itself as fleet operating efficiencies and the opportunities for companies to burnish their “green credentials” outweigh the near-term higher switching costs. Amazon has committed to having 100,000 electric delivery vans in its fleet by 2030, reducing carbon dioxide emissions by 4 million metric tons per year [8]. Again, widespread EV adoption rests on the assumption that these goals are achieved in the stated time frame.

The challenges to wider electrification have already been mentioned and perhaps deserve their own chapter in this book. While the lingering effects of COVID-19 are still to be determined, it is fair to conclude that smaller, more robust, regionalized supply chains are likely to result from current events. This effective “rebuild” of supply chains will take time, money, and political will. Combining all three is an enormous challenge, but there are examples to draw from historically such as the Marshall Plan which aided in rebuilding Europe in the wake of the Second World War. De-globalization is gaining appeal in 2020 as critical material dependence,

income inequality, and the fragility of the existing global supply chain system are laid bare for all to see.

A new example of battery supply chain regionalization concerns the European Battery Alliance and its strategic action plan to position batteries at the center of a new wave of industrialization in Europe [9]. The underlying strategy of achieving a degree of autonomy and owning next-generation intellectual property is of paramount importance and a key measure of long-term success.

Future cash flows and battery-inspired intellectual property, also highly valuable, are at stake. The call for more self-sufficiency in supply chain development will only grow louder as globalization shrinks and the opportunity to dominate a fast-growing sector becomes apparent to investors of all stripes. It is to investors that we now turn.

4. Investment risks and implications

Perhaps the most overlooked aspect of lithium ion supply chain growth is the most important—the funding. Many people assume that the rollout to mass electrified transit will be linear and relatively seamless, but history suggests that transformative change is anything but. While discussions of double-digit compound annual growth rates (CAGR) for raw materials are enticing, pairing adequate sums of capital optimally along the supply chain has proven to be a challenging exercise. This is due to the fact that the mining segment of this supply chain is subject to infrequent and enormous cyclical swings in pricing, leading to a traditional boom-and-bust cycle. As an example of a typical commodity cycle is shown in **Figure 2**.

Embedded in the capital cycle thematic are risks unique to strategic metals such as lithium and cobalt. These can be broadly grouped into four categories: financial, geopolitical, social, and technology.

Financial risks center on issues like access to capital, determining the cost of capital, commodity pricing, the effect of technology on cost, and macroeconomic headwinds or tailwinds. The cost of and access to capital are causally related to what point we find ourselves in the capital cycle. When lithium carbonate pricing peaked at roughly \$20,000 USD per ton in April 2018, equity share prices were at all-time highs, capital expansion plans were being announced on an almost daily basis, and capital was widely available. Fast forward to April 2020, equity share prices have crashed by as much as 65%, capital expansion plans have by and large

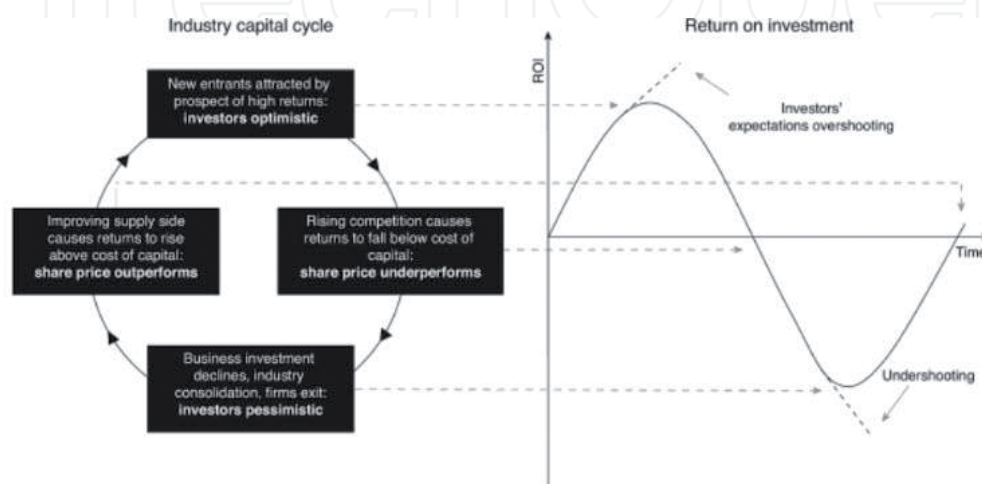


Figure 2. The typical boom-and-bust cycle and return on investment. Source: *Capital Returns: Investing through the Capital Cycle—A Money Manager's Reports 2002–2015*, by Edward Chancellor.

been shelved by lithium miners and project developers, and the capital that is available has much more stringent strings attached to it than before to compensate for elevated risk. While some of this retrenchment is related to COVID-19, the asset behavior is typical of a boom-and-bust cycle.

Geopolitical risks include resource nationalism, resource dependence, and a single country (China, in this instance) exerting control over most of the full supply chain for critical minerals. When lithium pricing spiked through 2017, calls to protect “the people’s lithium” from foreign exploitation in countries such as Chile only grew louder. The battery metals are somewhat unique in this regard as the small market size of lithium or cobalt (e.g., 300,000 tons per year and 140,000 tons per year, respectively) masks their strategic importance to next-generation technologies. Governments around the world such as the United States and the United Kingdom have designated these natural resources as “critical” and have proposed legislation to help lessen dependence on foreign adversaries [10] (Figure 3).

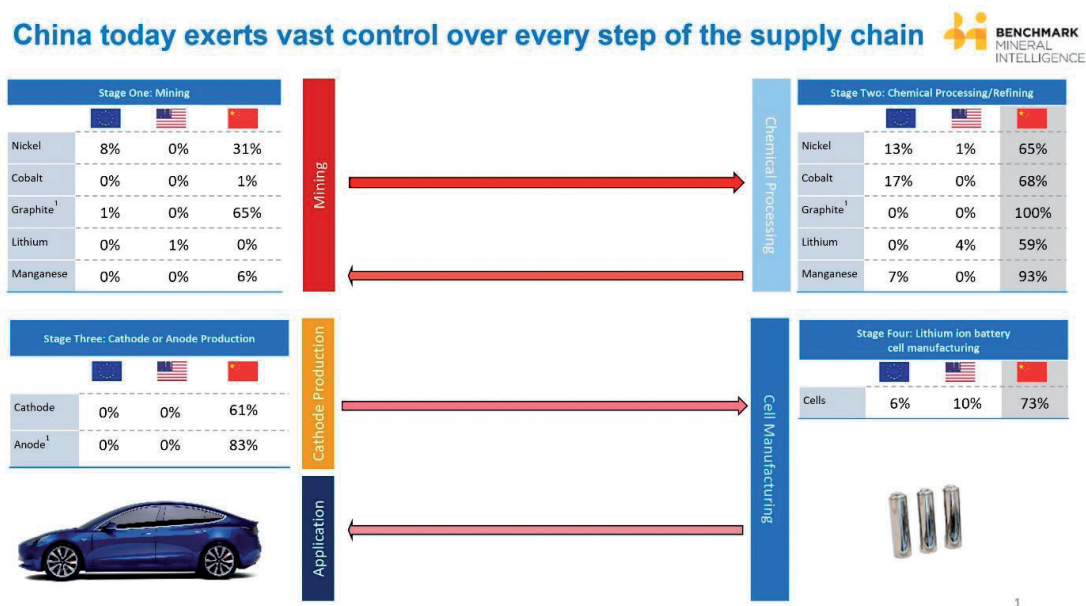


Figure 3. China’s dominance of all aspects of the EV supply chain is evident. Source: Benchmark Mineral Intelligence.

The social risks apply to the mining industry as a whole and have taken on new relevance with environment, social, and governance (ESG) mandates increasingly required by investors before committing any capital. What steps a company along the lithium ion supply chain is undertaking to minimize CO2 emissions is a notable example of renewed ESG focus. The recent questioning of globalization as an enabler of income inequality and the resulting explosion of populist sentiment is another example of the challenges lithium ion supply chain companies face amidst a backdrop of strong growth in the coming decade. How this growth will be financed given ESG mandates and how the wealth will be shared (if at all) are looming questions.

A final risk is centered on the role of technology. An example is the optimization and deployment of new technologies to lower costs in lithium extraction. Better known as direct lithium extraction (DLE) technologies, these technologies such as solvent extraction or ion exchange have the potential to reshape the lithium cost curve. While the technologies themselves are well known, the potential benefits to lithium include dramatically lower extraction and purification costs, mitigation of the need for large brine ponds, and reduction in the time it takes to produce high-purity lithium chemicals. While this technology is not scaled as of this writing,

there are a number of these processes competing for investor capital predicated on these benefits [11].

4.1 The trouble with pricing

The recent price swings in lithium and cobalt have caused more damage to capital availability in the lithium ion supply chain than benefit. Raw material price volatility presents one of the greatest challenges to lithium ion supply chain development in the next decade. Enormous sums are required to build additional production capacity, but excessive volatility in raw material pricing has typically kept all but the largest strategic investors out of the space. These strategic investors—mainly Asia-based banks or lithium and cobalt users—only have so much capital and so much capacity to process raw materials. A move to vertically integrate supply chains is believed to be the answer from the automakers, but this process will be somewhat slower than many would like as automotive supply chains as they exist today will not be able to “turn on a dime” and ramp production of EVs owing to the sunk costs of existing infrastructure. Perhaps the vertical integration strategy of Tesla or China’s view of owning most of the supply chain serves as a viable model going forward.

For the sake of reference, the typical greenfield lithium mine can have an upfront capital expenditure of \$500–600 M USD (inclusive of the mine, ore type, and processing plant) [12]. From discovery of the asset, through development, successful capital raising, deployment of the said capital, project build-out, and first production, the typical timing is 7–10 years. If consensus lithium demand is anticipated to grow by three times in the next decade, this would require at least \$10B USD in capital in an industry that traditionally generates only \$3B USD in revenue per year. Should EV demand accelerate ahead of consensus expectations, this \$10B figure could be conservative.

A challenge here for capital providers is that in addition to effectively timing the market and managing anticipated demand, the pace of change is accelerated when confronted with disruptive technologies such as battery chemistries or lithium extraction technologies. While lithium demand can increase at a linear rate, technological leaps can accelerate this demand just as COVID-19 can destroy it and wreak havoc with pricing.

Lithium ion battery chemistries such as lithium iron phosphate (LFP) are expected to lose market share quickly to their more energy dense cousins nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminum (NCA). This has not come to pass yet however for several reasons including improvements in LFP energy density [13] and lower overall raw material pricing which affects switching costs.

Aside from questions surrounding battery chemistries, the crash in equity share prices in Q1 2020 has served to push the typical investor into a “risk off” mentality despite global central banks effectively trying to backstop the financial markets and prop up asset prices using both monetary and fiscal levers. Without a healthy risk appetite in the markets, how will the CO2 reduction targets in the EU be achieved in time? How will China achieve its goal of 20% of new car sales in 2025 as EVs? The reality is that for these goals to be achieved, a flood of capital needs to come into the lithium ion supply chain in a hurry. Otherwise, the EV market will remain smaller for longer, with fewer winners who were initially willing to embrace risk and invest in supply chain development.

4.2 Visibility through futures contracts

The lithium industry has come together recently to produce a solution for the lack of ability to hedge price risk. The London Metal Exchange convened a working group in 2019 to build futures contracts for lithium chemicals [14]. These

contracts are aimed at providing price transparency across what has traditionally been a small, opaque market run in an oligopolistic fashion. The contracts are to be cash settled and will source pricing data from the members of the working group. As of April 2020, the contracts had yet to be introduced owing to logistical issues with price collection. Pricing data is highly proprietary in nature, and the futures contracts need this critical component to ensure widespread adoption across the industry. The opacity of pricing works to the advantage of lithium chemical producers such as Albemarle or SQM but acts as a detriment to potential capital providers who need pricing transparency and stability to commit capital at a reasonable cost for a significant length of time.

Owing to the traditionally small size of the market and highly specialized end products, lithium pricing has always been opaque with pricing determined on a contracted basis between the producer and buyer with a small spot market which exists in China for “off spec” material. Contract pricing between the producer and seller is a major piece of off-take agreements and is really driven by four criteria: the term of the contract, the amount of material for purchase, the quality of the material, and the depth of the relationship between producer and consumer. There can be a wide degree of flexibility in terms of typical off-take agreements in order to protect both producer and consumer from price volatility or other events which could require force majeure. A futures contract can help serve as an anchor to any off-take agreements.

5. Shared risks in capital allocation: a case study

While the immediate need for large sums of capital is clear, the source of this capital has traditionally been centrally located with Asia-based banks or end users such as battery manufacturers serving as off-take partners. While Asia, and China in particular, will remain the main engine of demand for EVs, other parts of the world such as the European Union are likely to become a larger part of the EV sales “pie.” This would indicate that sources of capital will need to become more diverse and perhaps serve local markets first. Given the typically large sums needed for initial capital expenditures, much of the capital comes in the form of debt instruments along with an equity component to ensure all stakeholder interests are aligned. The idea of trading offtake for financing has become a trusted model in the industry as the end users of lithium chemicals, for instance, typically have the robust balance sheets necessary to help with the financing of mining projects. One such case study is Pilbara Minerals, a lithium producer based in Australia. The company has executed several off-take agreements, but a good case study is the lithium concentrate agreement the company completed with Ganfeng lithium in 2017 [15]. This is far from the only off-take agreement Pilbara has executed, but what makes this deal unique is that it has multiple components. Ganfeng agreed to purchase up to 160,000 tpy of lithium concentrate, as well as taking a \$20 M AUD equity position in Pilbara and offered a debt funding/pre-payment facility to alleviate the financing challenges. This partnership model, where risk is spread across all stakeholders and both financing and technology challenges are mitigated, has been used with other lithium producers and off-take partners with success.

5.1 Capital allocation gone wrong: a case study

Lithium is an oligopoly, with Albemarle, SQM, Livent, Ganfeng Lithium, and Tianqi Lithium as the major lithium compound producers. During the most recent

bull market in lithium (2016–2018), these companies all pushed forward with project expansions, and M&A activity was scarce with one exception. Tianqi Lithium purchased a 24% equity stake in SQM in 2018 for \$4.066 billion USD. This deal raised several eyebrows in the lithium world in the sense that two fierce competitors were integrating their respective strategies with SQM giving up more in terms of market intelligence, pricing, and sales strategies and gaining much less. Tianqi's strategy was clear—the share purchase instantly made the company a major SQM shareholder and three board of director seats included with the equity position would ensure an intimate view of SQM's marketing strategy and expansion plans—plans that Tianqi could exploit to their own advantage. The deal was enveloped in controversy from the start in Santiago and ultimately while the transaction was completed successfully, a number of restrictions were placed on the three board seats [16].

The real capital allocation lesson from this deal, however, had yet to be learned. When Tianqi purchased the SQM Class A shares, they did so at a price of \$65 per share. The purchase was funded in part with a \$3.5B USD loan from CITIC Bank in China. Since the deal was completed, SQM share price has fallen by 65%. This, coupled with a dramatically lower lithium chemicals price, has caused severe liquidity issues for Tianqi, harming their credit rating which was subsequently downgraded to Caa1 with a negative outlook by Moody's in March of 2020 [17]. Adding a sense of urgency, around \$2B of the loan is due in November 2020. Essentially, Tianqi made a deal at the absolute top of the capital allocation cycle and must now work to strengthen its balance sheet at a particularly precarious and unpleasant point in lithium industry history. Unfortunate allocation decisions such as this harm investor confidence in the lithium sector and could delay much-needed funding for expansion.

6. Conclusion

The lithium ion supply chain has experienced twin shocks of a trade war and COVID-19 demand destruction against a backdrop of strong long-term growth dynamics. These forces have kick-started a re-think of globalized supply chains in the interest of national security and self-sufficiency. Even those who are bearish on EV demand see the market growing throughout this decade, and so it makes sense to ensure that supply chains are built with sustainability and resilience in mind as raw material demand experiences robust growth. Recent actions by the US, EU, and Chinese governments are but a taste of what is to come.

The decarbonization thematic goes together with de-globalization and is benefitting from the twin tailwinds of global government mandates to phase out the ICE and tech-driven cost deflation in the cost of lithium ion batteries. These forces will not remain in place indefinitely but however are set to create opportunities for a wider swath of investors. Assuming the rosy demand projections come to fruition, a robust and resilient lithium ion supply chain depends upon two things: successful capital accumulation and capital allocation. A world awash in liquidity indicates that capital accumulation is really a function of expected returns on given project and the best projects will attract enough capital to sustain themselves through the building and commissioning phases. The challenge comes with capital allocation, and there are many lessons learned here about how not to deploy capital rather than the opposite. In recent years, capital in the lithium ion supply chain has flowed from a small coterie of strategic investors given raw material price opacity, price volatility, and the generally small size of the markets. This will have to change if we are to meet most EV penetration forecasts in the future.

The lithium supply chain faces a dilemma. If decarbonization and EV sales penetration goals are to be met, much more capital is needed to fund mine and supply chain development today for a demand profile that only exists on paper. The checkered history of lithium mine capital accumulation and allocation does not lend confidence to those looking to invest, so how deals are structured will be a key to unlocking new sources of capital.

The unwieldy and unprecedented hydra-like growth of the lithium ion supply chain will offer multiple exciting opportunities to alter supply chains and achieve sustainable results for all stakeholders well into the future. The lynchpin for success is successful capital accumulation and deployment.

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Conflicts of interest

The author declares no conflicts of interest.

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