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Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles

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Abstract

Lithium is an essential material in the production of lithium-ion batteries (LIBs), which power electric vehicles. This paper examines the global value chain (GVC) for lithium as part of a series of working papers that map out the global sources of mining, refining, and value-added for the key LIB materials. Results show that few countries have economically viable resources of the upstream raw materials that supply the lithium GVC. Most lithium-rich ores are exported from Australia to China for processing, while most lithium brine concentrates are exported from Chile to South Korea, Japan, and China for processing. The large inflows of lithium to China support its dominant position in the downstream refining process, which is where the largest share of value-added occurs. Consequently, China is capturing the largest shares of value-added along the lithium GVC, despite lacking in resource endowment.

U.S. International Trade Commission

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U.S. International Trade Commission

GVC: Lithium in Lithium-ion Batteries for Electric Vehicles

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Introduction

This article is one of five working papers in a series dedicated to examining the global value chains (GVCs) of the key materials—cobalt, lithium, graphite, and nickel—that are critical to the composition of lithium-ion batteries (LIBs) that power electric vehicles (EVs).[1] Lithium is a strategically important, global commodity because of its use in batteries that not only power electric vehicles but also a wide range of personal electronics items. Demand for EV LIBs is a significant factor in the rise in of demand for lithium, and projections by industry experts attribute most of the future growth in demand for increased lithium consumption to LIBs used in EVs.[2]

Lithium is differentiated in terms of profitable production—lithium production costs vary significantly depending upon the type of raw mineral and lithium concentration. Although there are several countries with upstream lithium endowments, there are only a few countries with lithium resource deposits that can be economically extracted to supply the lithium GVC. The first supply chain is the largest bilateral trade pattern involving unprocessed lithium minerals. These unprocessed lithium minerals are mostly exported from Australia to China where they are refined and then consumed. The second supply chain involves the shipment of processed lithium compounds which are principally sent from Chile to Japan, South Korea, and China. China holds a dominant role in the downstream refining process, which is where the largest share of value-added occurs. China's dominance in the downstream refining is a result of aggressive growth by private firms, such as Tianqi and Ganfeng.

This working paper examines how and where lithium is mined and refined. The first section of this paper provides an overview of the role of LIBs in EVs. The second section investigates the attributes and role of lithium in LIBs. The third section analyzes lithium market trends and the importance of price. The fourth section examines each of the various lithium commodity forms identified in table 1. The discussion for each form includes three subsections that explore the form's production processes, production locations and international trade flows, and a case study. Additionally, the production stages that countries and firms participate in are discussed to highlight where the value-added activities of the GVC occur. There are three geographic case studies covered in the market profile section of each commodity group: the first involves Australia, the largest source of unprocessed lithium (HS 2530.90); the second examines Chile, which is a major source of processed lithium chemicals (HS 2836.91 and 2825.20); and, the third explores China, the world's largest producer of processed lithium chemicals (HS 2836.91 and 2825.20) and refined lithium compounds (HS 2805.19, 2826.90, and 2827.39). The last section of the paper discusses lithium GVC indicators associated with trade.

Table 1 shows the three main forms of lithium discussed throughout this paper. These three forms can be defined at the global Harmonized System (HS) 6-digit subheading level. The related subheadings are unprocessed lithium (HS 2530.90), referred to as "raw stage 1;" processed lithium (HS 2836.91 and 2825.20), referred to as "raw stage 2;" and, "refined" lithium products (HS 2827.39, 2826.90, and 2805.19).

[1] Forthcoming working papers by the USITC staff in the Natural Resources and Energy Division of the Office of Industries, related to the global value chains for four key materials—lithium, cobalt, nickel, and graphite—used in the production of lithium-ion batteries cell.
[2] Jaskula, "Mineral Commodity Summary: Lithium," January 2020.

Table 1 Lithium product forms, by HS subheading and source

Form of lithium (process stage)	HS subheading	Description	Source(s) type	Geographic source(s)
Unprocessed lithium minerals (raw stage 1)	2530.90	Other mineral substances, not elsewhere specified or included	Mine extraction	Australia, China, Argentina, Zimbabwe
	N/A[a]	Lithium rich salt concentrates	Brine extraction	Chile, Argentina
Processed lithium chemicals (raw stage 2)	2836.91	Lithium carbonate	Lithium rich ores and salt concentrates	Chile, China
	2825.20	Lithium oxide and hydroxide	Lithium rich ores or lithium carbonate	China
Refined lithium compounds	2827.39	Chlorides, not elsewhere specified or included	Lithium carbonate	China, South Korea, Japan
	2826.90	Other Fluorides, fluorosilicates, fluoroaluminates and other complex fluorine salts	Various lithium compounds, such as lithium chloride, lithium hydroxide, or lithium fluoride.	China, South Korea, Japan
	2805.19[b]	alkali metals, other than sodium	Lithium chloride	China, South Korea, Japan

[a] There are no specific HS numbers differentiating unprocessed salts based upon lithium content. Unprocessed lithium rich salt concentrates are not widely traded. Lithium salt concentrates are typically processed at or near extraction operations.
[b] Lithium metals would be imported under this HS subheading.

Electric Vehicle Lithium-Ion Batteries

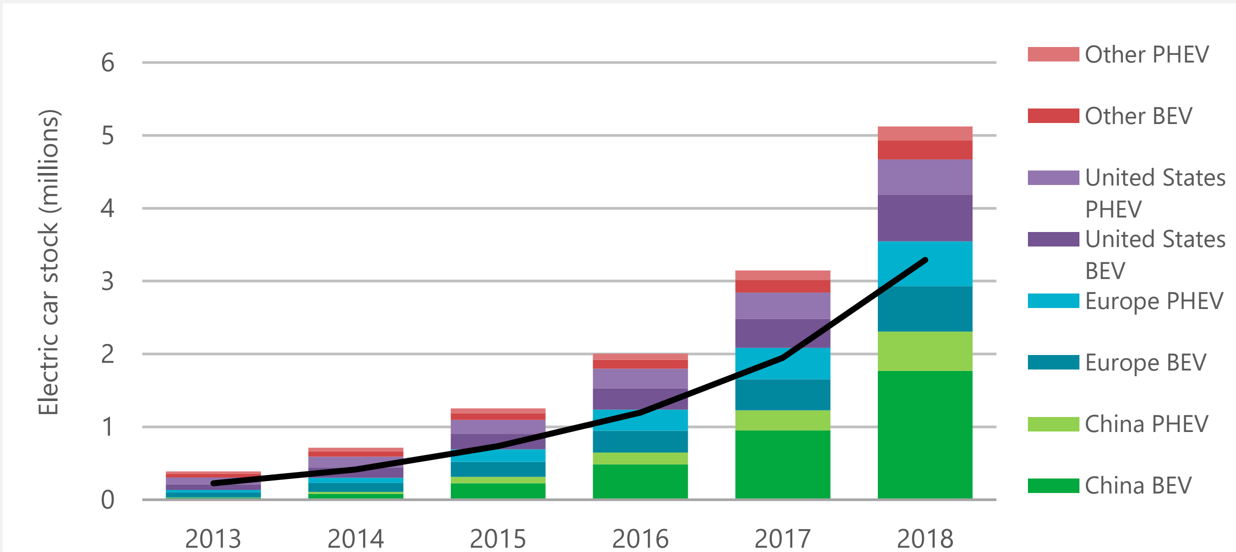
Although LIBs power EVs as well as many consumer electronics, EVs are projected to become the dominant end-use for LIBs. Consumers' growing demand for EVs is largely driven by their potential to reduce carbon dioxide (CO_2) emissions and other pollutants compared to internal combustion engine (ICE) vehicles. In addition, EV demand growth is also partly attributable to declining battery prices and government incentives to defray costs.[3] These lower battery prices reflect LIB cost improvements in the global supply chain (GSC) for key LIB materials and battery technology innovations. Previous research has examined the importance of EV batteries (LIBs) and their inputs, including the related supply chain.[4]

As noted above, demand for EV LIBs is a significant driver of demand for lithium and accounts for most of the projected future growth.[5] Lithium used in batteries accounted for 77.5 percent of the increased global demand for lithium from 2010 to 2017.[6] World sales of battery and plug-in hybrid EVs reached approximately 2.1 million vehicles in 2018 (figure 1).[7] Rising demand from the automotive industry,

[3] Scott and Ireland. "Lithium-ion Battery Materials and Their Global Value Chains: An Overview." Forthcoming.
[4] Coffin and Horowitz, "The Supply Chain for Electric Vehicle Batteries," 2018; and Kwon and Ryou, "Global Value Chains of East Asia: Trade in Value Added and Vertical Specialization," 2015.
[5] Jaskula, "Mineral Commodity Summary: Lithium," February 2019.
[6] Azevedo et al., "Lithium and Cobalt: A Tale of Two Commodities," June 2018.
[7] Irle, "The Electric Vehicle World Sales Database," Ev-volumes.com, accessed August 9, 2019.

particularly in the use of batteries for EVs, has led to a significant rise and fall in global prices since 2015 (figures 4 and 5).[8] In 2017, prices for processed lithium chemicals spiked due to concerns regarding supply constraints.[9] By contrast, during late 2018 and through 2019, prices decreased due to production exceeding demand for lithium.[10]

Figure 1 Electric car deployment in selected countries, 2013–18

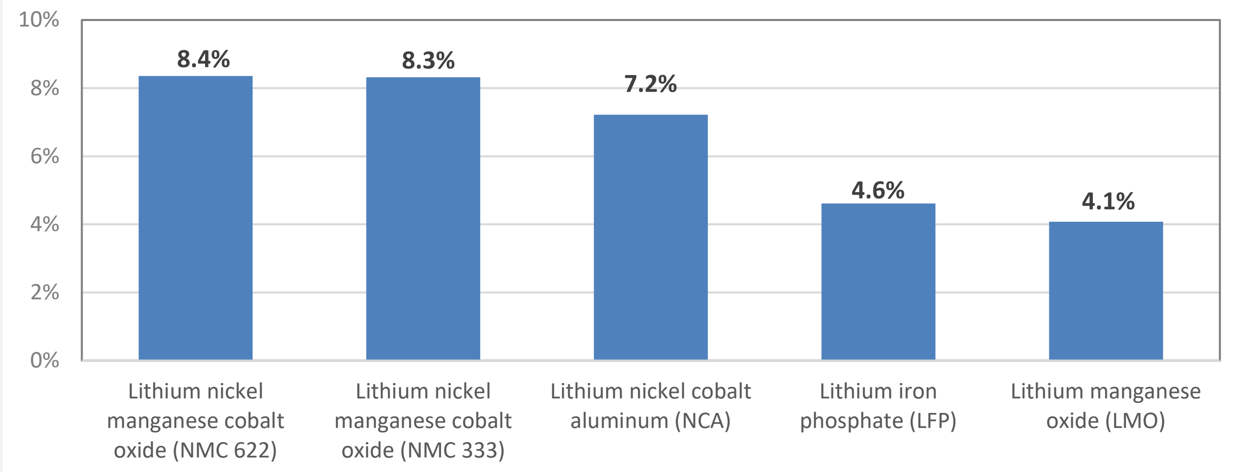


Source: IEA, "Electric car deployment in selected countries, 2013-2018," retrieved January 22, 2020.
Note: BEV refers to a battery electric vehicle without a gasoline-based engine. PHEV denotes a plug-in hybrid vehicle, which has a battery and gasoline-based engine.

There are a variety of LIBs currently in use in EVs—the principal difference between the batteries is their composition (figure 2). Lithium's percentage share in the active material in the different types of battery cathode by volume ranges from 4.1 to 8.4 percent for the five major types of LIB cells.[11] Despite its relatively low content share relative to other materials, lithium is a crucial element in these batteries with a volume content similar to that of cobalt.[12] Figure 2 shows the five most common cathode material battery-types for EV LIBs, with nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminum (NCA) being are the most prevalent. NMC batteries are further divided based upon the proportion of materials. NMC-622 has three-times the nickel content relative to manganese or cobalt; whereas NMC-333 has an equal proportion of nickel, manganese, and cobalt. EV buses utilize LIBs composed of lithium iron phosphate (LFP).

[8] Azevedo et al., "Lithium and Cobalt: A Tale of Two Commodities," June 2018.
[9] Shankleman et al., "We're Going to Need More Lithium," September 7, 2017.
[10] Sanderson, "Lithium hit by oversupply and electric vehicle subsidy cuts," August 26, 2019.
[11] Argonne National Laboratory, "BatPac: A Lithium-Ion Battery Performance and Cost Model for Electric-Drive Vehicles," June 28, 2018.
[12] Robert Morris, *Electric Vehicle Revolution and Implications for New Energy Metals*, April 26, 2015.

Figure 2 Lithium composition share in selected LIB cathodes, by volume, 2018



Source: Argonne National Laboratory, "BatPac: A Lithium-Ion Battery Performance and Cost Model for Electric-Drive Vehicles," June 28, 2018.

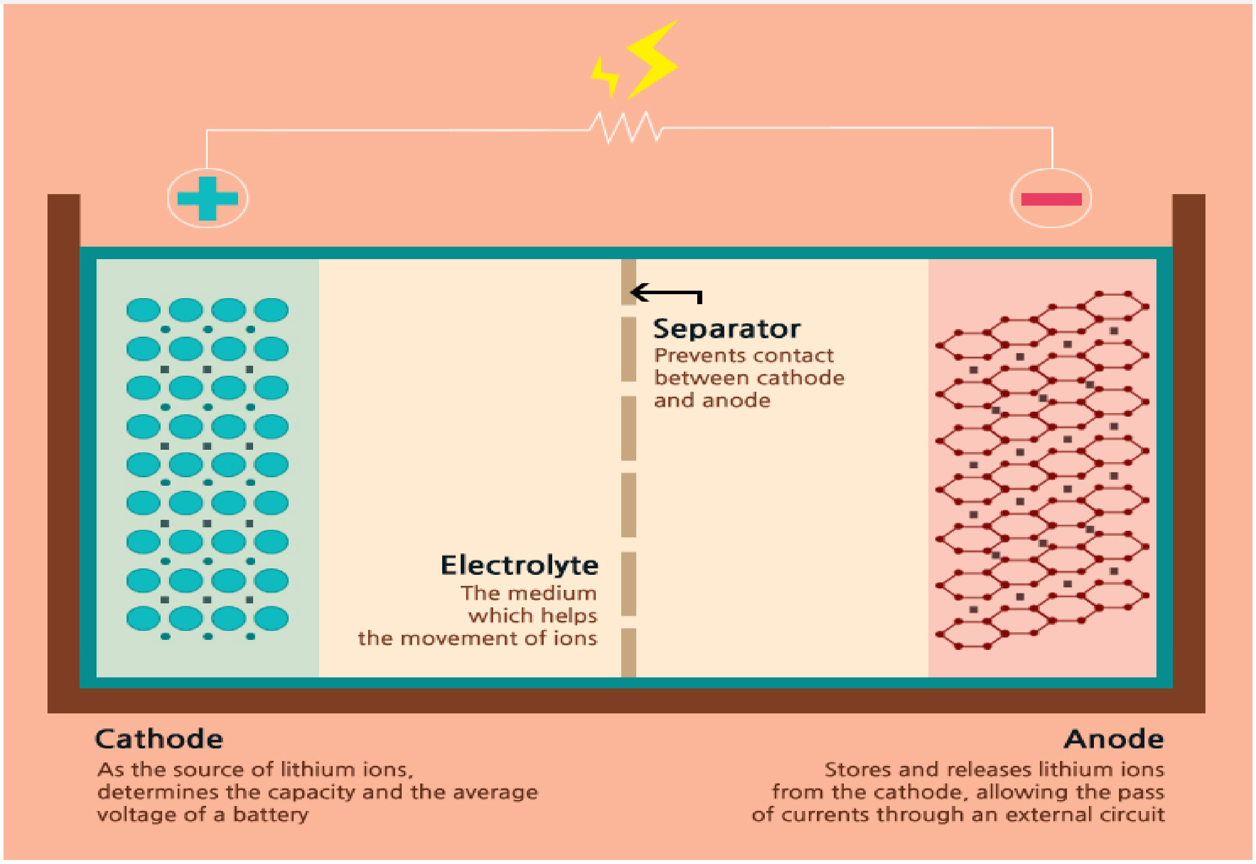
Lithium Attributes and LIB Role

Lithium is a metal valued for its low atomic mass and electrochemical reactivity.[13] Lithium's chemical characteristics allow for LIBs to be lighter and more energy dense than alternative battery metals. It is the reactive chemical element that allows an electrical charge to be stored and used, and lithium is employed as an active material in the cathode and electrolytic solution of LIBs.[14] LIBs are named after the lithium ions that carry charge and allow batteries to be charged and discharged. Figure 3 is an abstract depiction of a LIB and various components.

[13] Royal Society of Chemistry, "Periodic Table: Lithium," accessed July 23, 2019.

[14] The cathode and electrolyte of LIBs require lithium. The cathode is the positive electrode where incoming electrical energy triggers lithium ions to be released. The electrolyte allows for lithium ions to pass between the cathode and anode. The electrolyte permits the charging and discharging of electric ions the battery. Lithium metal batteries, which are currently in development, aim to replace anode graphite with lithium.

Figure 3 The four components of lithium-ion battery



Source: Samsung SDI, *The Four Components of a Lithium-Ion Battery*, retrieved January 22, 2020.

Currently, there are no substitute materials for lithium that have comparable energy density in battery applications. However, global supply concerns and price volatility have led to increased battery materials research to find potential alternatives.[15] The supply concerns regarding lithium center on achieving profitable extraction; although abundant in several locations, lithium deposits often exist in low levels of concentration. Certain ongoing research involving emerging battery technologies aims to replace lithium with more commercially viable chemical elements, such as sodium and fluoride.[16] These alternate configurations face a common challenge, however, which is that the batteries using these materials require a high temperature to function. This high operating temperature is inefficient and potentially unsafe.[17] Thus, lithium is expected to continue to play a leading role in rechargeable batteries for the foreseeable future. Moreover, several next-generation battery technologies in development continue to use lithium, such as solid-state and lithium-metal batteries.[18]

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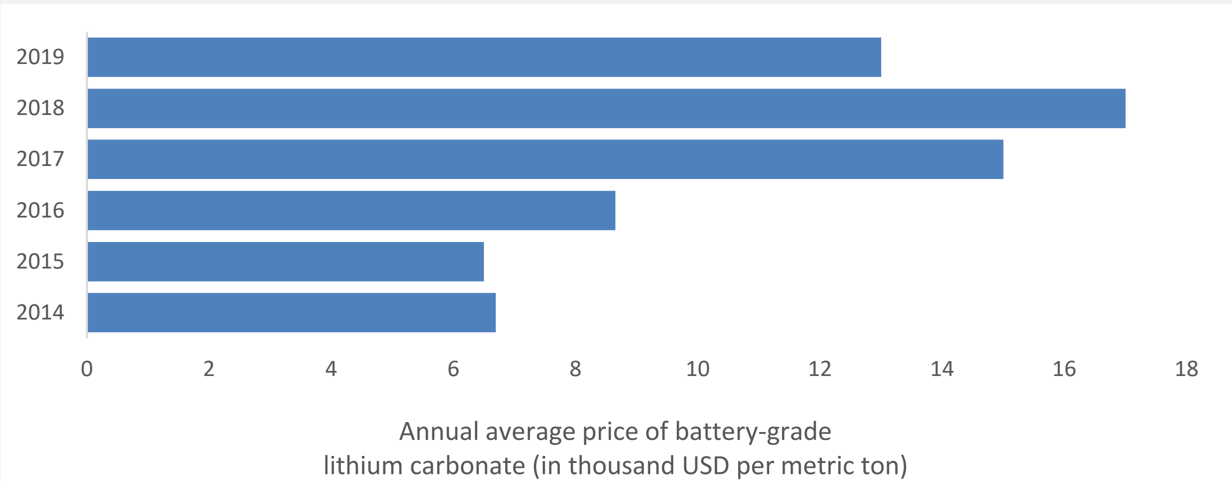
[15] Ashley Hamer, “4 Up-and-Coming Batteries that could Overtake Lithium-Ion,” January 22, 2019.
[16] University of Birmingham, “New High-Capacity Sodium-Ion Could Replace Lithium in Rechargeable Batteries,” September 12, 2018 and Jacoby, “Fluoride-Ion Battery Runs at Room Temperature,” December 10, 2018.
[17] University of Wollongong, “Sodium-ion battery packs a punch,” April 5, 2018.
[18] Evarts, “GM Wins US Grant to Develop Solid-State Batteries,” August 27, 2019; and David Grossman, “Lithium Metal Could Soon Replace Lithium Ion in Batteries,” August 29, 2019.

Lithium Market Trends

As noted earlier, although the raw materials needed to produce lithium are plentiful and abundant throughout the world,[19] the challenge for lithium producers is achieving and maintaining profitable extraction.[20] Lithium occurs naturally in relatively diluted forms that must be processed to yield highly concentrated lithium compounds (see the unprocessed lithium compounds section for more information). Production costs vary depending upon the type of raw mineral and lithium concentration,[21] and production/extraction decisions are made based upon the commodity prices of lithium compounds. Smaller producers with less concentrated deposits of lithium often can only profitably extract lithium at relatively high commodity prices.

Publicly available price information on unprocessed lithium minerals and refined lithium compounds is lacking. The available price information on processed lithium chemicals, namely lithium carbonate and lithium hydroxide, is typically in either annual or limited monthly formats (figures 4 and 5). The annual average price depicted in figure 4 shows the change in lithium prices since 2014. Note that lithium hydroxide has a price premium over lithium carbonate, which is somewhat attributable to its use in EV LIBs.[22] The lack of publicly available pricing data on different lithium commodities increases the difficulty of tracking the degree to which value-added activities occur throughout in the lithium GVC.

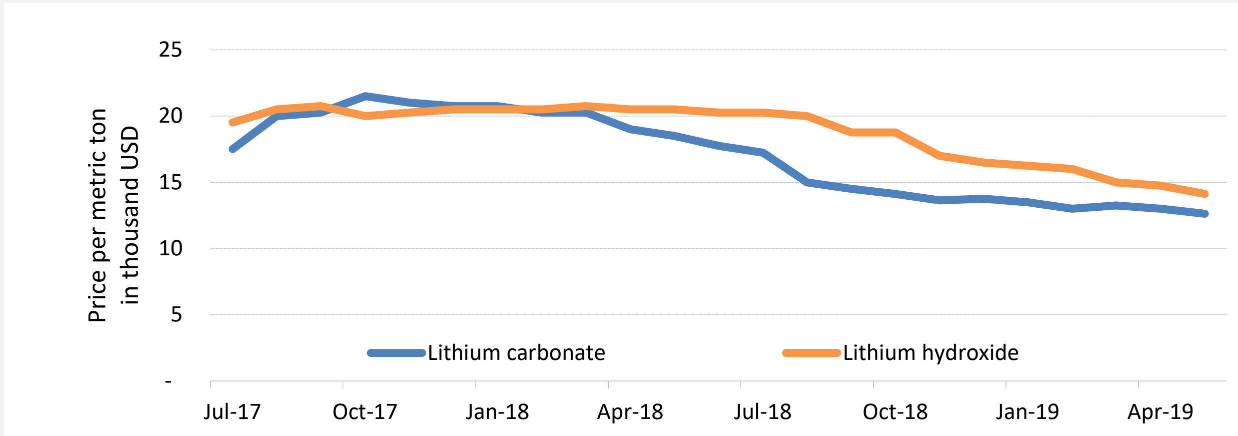
Figure 4 Unprocessed lithium (raw stage 1) price trends, 2014 to 2019



Source: Jaskula, "Mineral Commodity Summary: Lithium," January 2020; Graphic developed by USITC staff.

[19] Jaskula, "Mineral Commodity Summary: Lithium," January 2020.
[20] A longer discussion on the difference between lithium carbonate and lithium hydroxide occurs in the processed lithium chemicals section. Kanellos, "Is There Money to Be Made in Lithium Mining?" August 29, 2016.
[21] Morris, "The era of the electric car promises…," April 26, 2019.
[22] Morris, "The era of the electric car promises…," April 26, 2019.

Figure 5 Lithium carbonate and lithium hydroxide prices, from July 2017 to June 2019



Source: Lu, "LME-Fastmarkets and the Future of Lithium Pricing," BloombergNEF, June 18, 2019.
Note: prices are for CIF spot swaps in China, Japan, and South Korea.

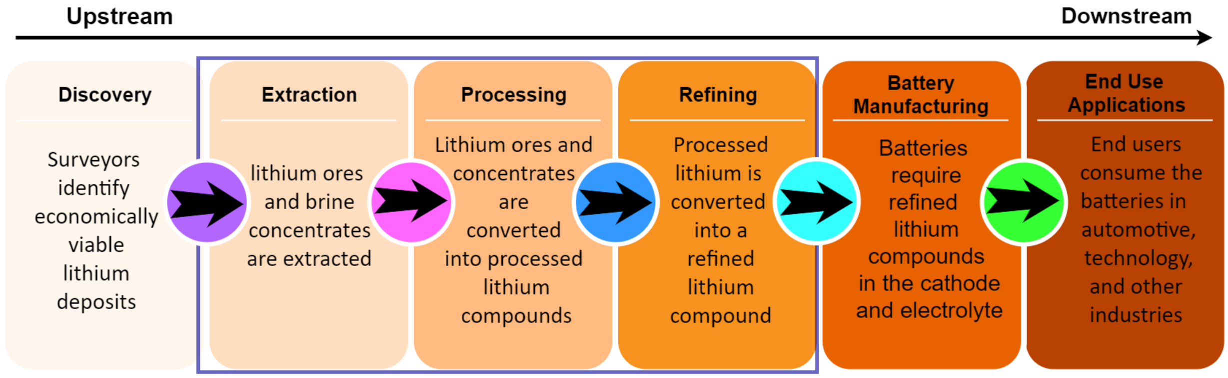
The amount of lithium produced is strongly influenced by the commodity's price. The rise of the EV industry and anticipated growth in demand for lithium have created supply concerns that resulted in higher prices for the commodity.[23] In fact, the rising price of lithium in 2017 (figure 4) resulted in firms entering the extraction industry and rapid growth in global lithium output (table 2). Since 2017, prices have fluctuated, but trended downwards as spot prices for lithium carbonate have declined, particularly in China due to decreased supply concerns and lower than anticipated demand growth.[24]

Processing

As a crucial component used in the production of LIBs for EVs, lithium's GVC and GSC involve a complex trading system with the sourcing of crude materials, processing, and refining of lithium tending to occur in different geographic locations (figure 6).[25] There are four major segments in the lithium GVC, adding value at each stage, these are: 1) mining and extraction of lithium rich-ores and brine-concentrates, 2) lithium processing and refining, 3) LIB production, and 4) EV manufacturing.[26] The largest bilateral trade pattern involves unprocessed lithium minerals (HS 2530.90). These unprocessed lithium minerals are exported from Australia and imported into China where they are processed, refined, and consumed. Argentina, Chile, the European Union (EU), Korea, Japan, and the United States are important secondary hubs of activity in the EV industry.

[23] Scheyder, "FMC Says Lithium Pricing Rising on Strong Electric Car Demand," August 2, 2018.
[24] Home, "COLUMN-Boom-and-Bust Lithium Market Needs a Pricing Rethink: Andy Home," June 24, 2019; and Heppel, Chen, and Jeary, "Lithium prices crash through $10,000 as hype meets reality," August 20, 2019.
[25] Other metals and minerals commonly used to create lithium-ion batteries include cobalt, graphite, and nickel.
[26] Throughout this report, the global lithium industry refers specifically to lithium used in lithium ion batteries used in EVs, although lithium is used in other end use applications.

Figure 6 Lithium processing flow chart



Source: Willis et al, “Australia’s Opportunity in the Lithium Battery Boom,” January 30, 2018; Graphic developed by USITC staff.
Note: The lithium processing steps covered in this paper are outlined by the blue box. Upstream operations refer to discovery through refining, while downstream operations refer to processes that result in a final product closer to the ultimate end use.

Unprocessed Lithium Minerals

There are two main sources (table 1) of the naturally occurring minerals that serve as feedstock for refined lithium: mining (which produces lithium ores—raw stage 1) and brine extraction (which produces lithium concentrates—raw stage 2).[27] Mining operations collect lithium from rock deposits, typically from open-pit mines. By contrast, brine extractions use solar evaporation ponds to distillate lithium salts. Lithium brine concentrates tend to be processed into lithium carbonate at source countries, which is covered more fully in the section on the processed lithium chemicals (HS 2836.91 and 2825.20) section. EVs use lithium from either type of deposit; however, lithium from mine deposits has a cost advantage when producing EV LIBs (for more information see the processed lithium chemicals section). Naturally occurring lithium ores include petalite, lepitate, spodumene, and others that have high concentrations of lithium (HS 2530.90).[28]

Table 2 shows that unprocessed (raw) lithium mineral production has increased substantially over the last five years as the production of EVs modestly increased as battery prices have decreased.[29] Australia is, by far, the largest producer of raw lithium (figure 7). The second largest source of raw lithium is Chile, which has several operations based the Atacama Desert near the border with Argentina and Bolivia. Argentina and Bolivia have substantial lithium reserves and are currently developing production capacity. (Chile, Argentina, and Bolivia tend to further process their lithium material before exporting; therefore, their export data are not included in figure 8.) China has a small but rapidly growing lithium extraction industry with both brine and mineral operations.

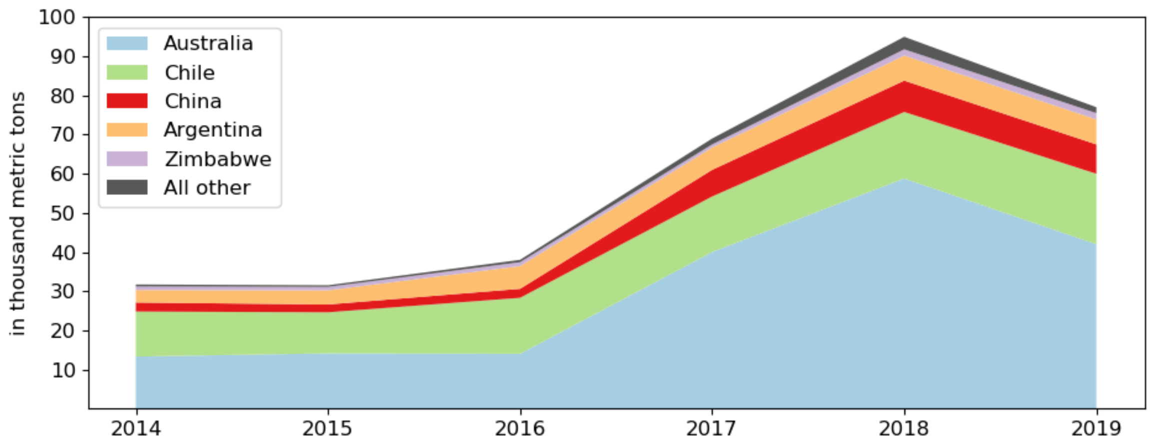
[27] It is possible to extract lithium from clay and oil deposits. These technologies and extraction methods are not widely adopted but may be an emergent production process. There are some alternative lithium extraction technologies currently in development, such as oil-based lithium extraction. However, none of the alternative lithium extraction technologies produces at a scale comparable to brine or mining operations.
[28] DeYoung et al, “Critical Mineral Resources of the United States - Economic and Environmental Geology and Prospects for Future Supply,” December 19, 2017.
[29] Logan Goldie-Scot, “A Behind the Scenes Take on Lithium-Ion Battery Prices,” March 5, 2019.

Table 2 Global production of unprocessed lithium minerals (raw stage 1 and raw stage 2), metric tons, 2014–18

Country	2014	2015	2016	2017	2018	2019
Australia	13,300	14,100	14,000	40,000	58,800	42,000
Chile	11,500	10,500	14,300	14,200	17,000	18,000
China	2,300	2,000	2,300	6,800	8,000	7,500
Argentina	3,200	3,600	5,800	5,700	6,400	6400
Zimbabwe	900	900	1,000	800	1,600	1,600
All other	500	400	600	1,500	3,200	1,500
Total	31,700	31,500	38,000	69,000	95,000	77,000

Source: Jaskula, "Mineral Commodity Summary: Lithium," January 2020.
Note: 2019 data are estimated by USGS. U.S. Production data have been withheld. Figures are in pure lithium content, which is 100 percent lithium.

Figure 7 Global production of lithium (measured in pure lithium content), 2014–19



Source: Jaskula, "Mineral Commodity Summary: Lithium," January 2020; Graphic developed by USITC staff.

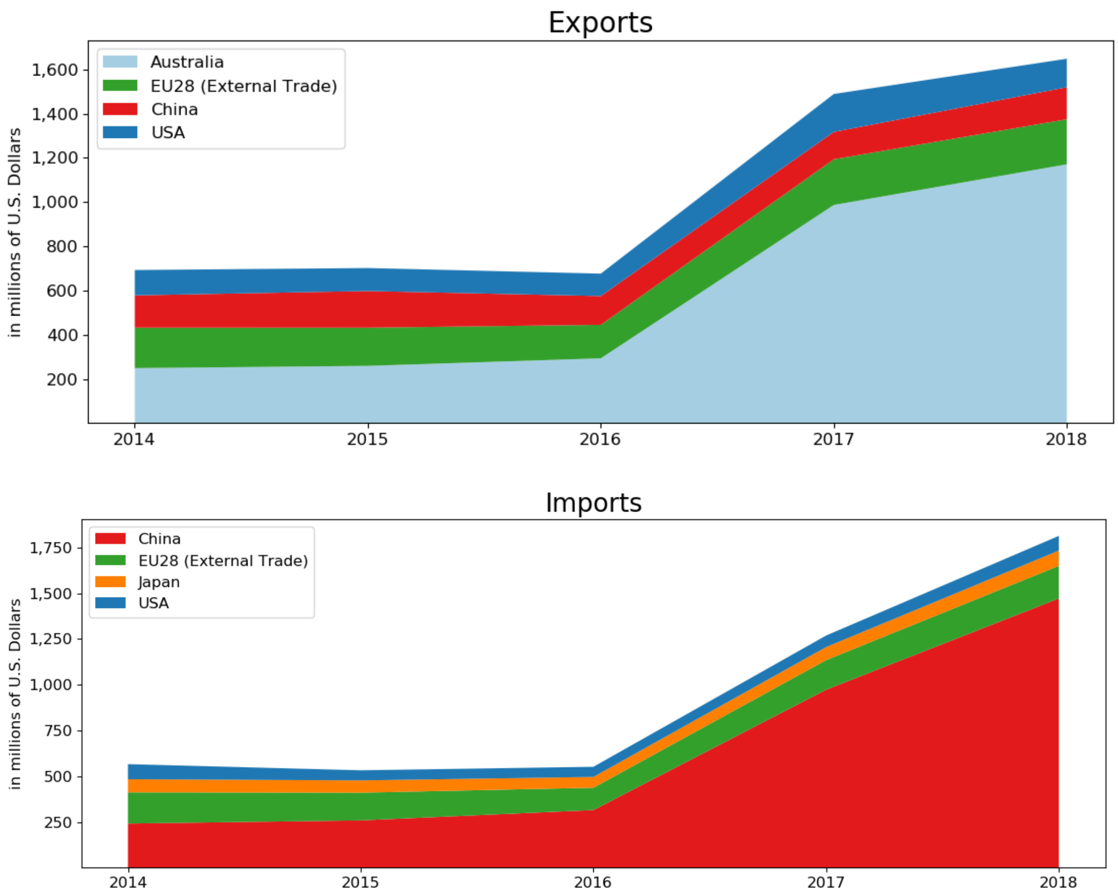
Trade: Unprocessed Lithium Minerals

The main story in the trade of unprocessed lithium minerals (raw stage 1, HS 2530.90) is the bilateral lithium trade relationship between Australia and China. By 2017, Australia had emerged as the principal exporter of lithium minerals and China as the leading importer (figure 8).[30] Global trade of unprocessed lithium minerals increased dramatically in 2017, due to a significant increase in exports from Australia as the Greenbushes mine began operations. Most of the increased exports from Australia were to China, where they were processed, refined, and consumed to power China's LIB industry, which in 2018 accounted for 61 percent of global battery production (table 3).[31] A more comprehensive analysis of the Chinese LIB industry occurs in the refined lithium compounds' market profile section. The bilateral share

[30] Given the broad HTS category, it is unclear if exports from the European Union and United States are unprocessed lithium minerals or other alkali minerals. The United States has lithium extraction operations using both mineral and brine. The European Union's lithium extraction operations are exclusively mineral deposits. The United States and the European Union produce all forms of processed lithium chemicals and refined lithium compounds covered in this paper.
[31] Desjardins, "Battery Megafactory Forecast: 400% Increase in Capacity to 1 TWh by 2028," October 19, 2018.

of trade between Australia and China in these materials increased from 53.9 percent in 2014 to 93.4 percent, indicating a strong and increasing trade relationship.

Figure 8 Global exports and imports of unprocessed lithium minerals (raw stage 1, HS 2530.90)



Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; Graphic developed by USITC staff.
Note: Official trade statistics for subheading 2530.90 of the global Harmonized System (HS) of tariff classifications. The HS code examined does not exclusively cover lithium minerals. Rather, it comprises a basket category of minerals some of which may have no application for EVs. Discrepancies in import and export values are likely due to reporting issues in the Global Trade Atlas. Export figures are based on "mirror data," which are derived using export statistics from partner countries' import data.

Table 3 Australia's exports of unprocessed lithium minerals (HS 2530.90) to the world and China, by value (millions of U.S. dollars)

Year	Exports to China	Total exports	China's share of the total
2014	134.2	248.9	53.9
2015	139.9	258.9	54.0
2016	188.4	293.2	64.3
2017	878.4	987.0	89.0
2018	1,093.2	1,170.8	93.4

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019.

Market Profile: Unprocessed Lithium Minerals from Australia

Australia is the world's dominant producer (figure 7) and exporter of unprocessed lithium minerals (raw stage 1, HS 2530.90). All lithium extraction operations in Australia are based on mineral mining and are located in the western part of the country.[32] The largest lithium mining firms in Australia are Talison Lithium,[33] Mineral Resources, and Chinese-headquartered Jiangxi Ganfeng Lithium ("Ganfeng"). Talison Lithium operates a major lithium mine in Western Australia called "Greenbushes," with an annual capacity of 1.34 million metric tons of lithium ores.[34] This production capacity is equal to approximately 50.9 thousand metric tons of lithium content and 59.9 percent of 2018 global lithium production.[35] Greenbushes Mineral Resources and Ganfeng operate a mine in Mount Marion, Australia that produced 418.7 thousand metric tons of spodumene concentrate (or 15.9 thousand metric tons of lithium content) in 2018.[36]

Eighty percent of Australia's lithium production reportedly goes to China,[37] all of which are unprocessed mineral ores (raw stage 1, HTS 2530.90).[38] These mined mineral ores tend to be are processed, refined, and turned into batteries in China, and possibly re-enter Australia as electric vehicles. A more comprehensive analysis of the Chinese LIB industry occurs in the refined lithium compounds' market profile section.

Australia seeks to capitalize on its abundant reserves to secure a larger position in the lithium battery supply chain. Currently, Australian firms export lithium minerals to China due to the scale of the Chinese industry and the demand for lithium minerals there. As the potential market for EV continues to grow, Australian authorities are seeking to become more involved in the downstream activities involved with the battery metals GVC. As of December 2018, the Australian government implemented tax offset incentives for firms related to the chemical processing and battery cell manufacturing.[39] Several companies are working to construct and operate lithium hydroxide processing plants in Australia, such as Tianqi, Albemarle, and Covalent Lithium.[40] These upcoming plants are expected to compete with plants in China that create lithium hydroxide. Australian exports of lithium hydroxide to the United States will be tariff exempt under United States-Australia Free Trade Agreement.

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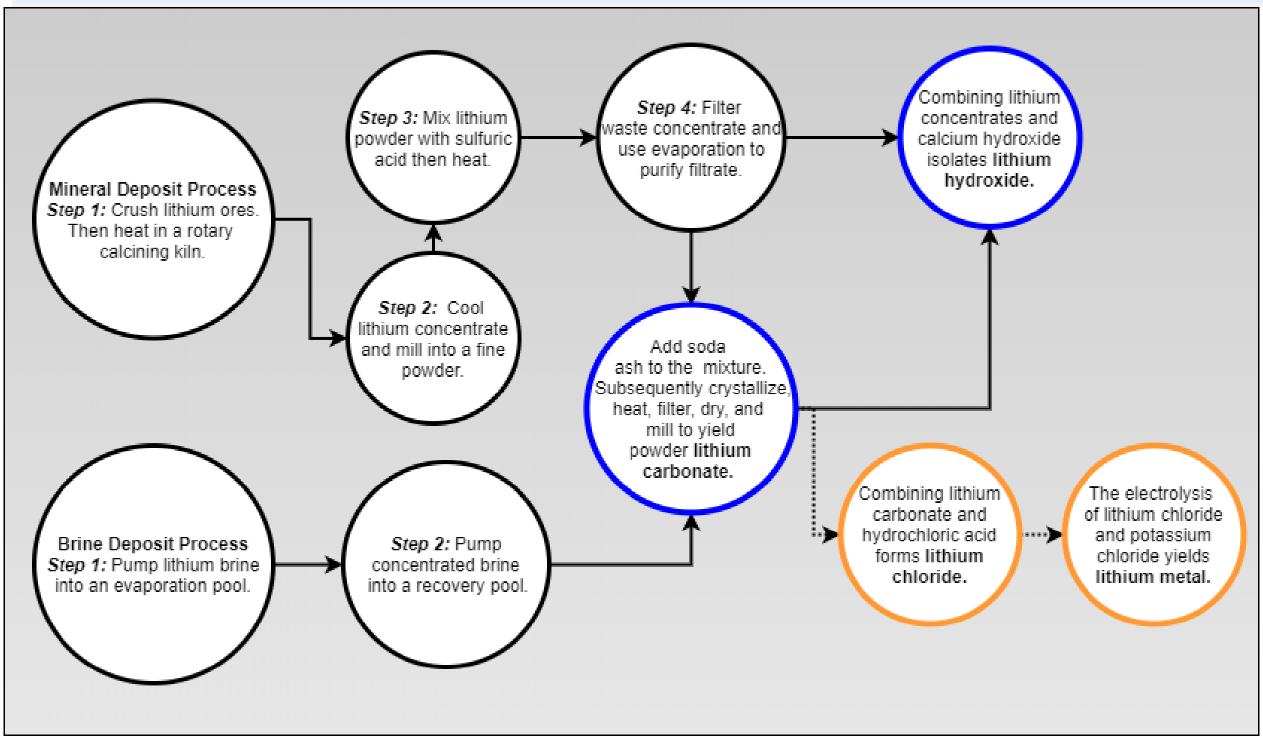
[32] Reuters, "Game of Mines," accessed July 18, 2019; and Burton, "Australian Miners Steam Ahead with Lithium Exploration," August 9, 2018.
[33] A joint venture between Tianqi and Albemarle. Talison Lithium, "About," accessed July 23, 2019.
[34] Talison Lithium, "Greenbushes Project," accessed July 23, 2019; and Leni, "The Lithium Supply and Demand Story," January 30, 2017.
[35] Leni, "The Lithium Supply and Demand Story," January 30, 2017.
[36] Facada, "Mineral Resources' Mount Marion Lithium Spodumene Production down in First Quarter," May 1, 2019.
[37] Azevedo et al, "Lithium and Cobalt: A Tale of Two Commodities," June 2018.
[38] IHS Markit, Global Trade Atlas, accessed August 16, 2019.
[39] Burton, "Australia Government Launches Strategy to Develop Itself as Battery...," December 11, 2018
[40] Australian Trade and Investment Commission, "The Lithium-ion Battery Value Chain," December 2018.

Processed Lithium Chemicals

After the unprocessed lithium minerals (ores and concentrates) have been extracted, they are treated and concentrated into processed lithium chemicals (raw stage 2) (table 1). Processed lithium chemicals refer to intermediary forms of lithium, such as lithium carbonate and lithium hydroxide. Lithium carbonate and lithium hydroxide are traded internationally under HS subheadings 2836.91 and 2825.20, respectively. Lithium carbonate and lithium hydroxide are inputs used to create cathode materials or further processed to create the battery electrolyte. Lithium ores (typically from Australia) and brine concentrates (typically from Chile) undergo different concentrating processes depending upon the unprocessed starting material and final chemical compound. Figure 9 illustrates how naturally occurring materials are converted into certain processed lithium chemicals (such as lithium carbonate and lithium hydroxide) and then into refined compounds (such as lithium chloride and lithium metal). The identified forms of refined lithium serve as inputs in the production of LIBs, which will be discussed in the refined lithium section.

Figure 9 Converting unprocessed lithium minerals into processed lithium chemicals and refined compounds



Source: IHS Market Chemical Economics Handbook Lithium, Lithium Minerals and Lithium Chemicals; Graphic developed by USITC staff.
Note: Circles with a black border refer to commodities that are categorized as unprocessed lithium minerals. Product isolations with blue borders are categorized as processed lithium chemicals. Product isolations with orange borders are grouped as refined lithium compounds. Lithium carbonate and lithium hydroxide are the two processed product isolations of interest for use in the cathode materials for EV batteries.

The discrete product isolations identified in figure 9 are used to create LIBs. Mineral and brine deposits have certain advantages when producing specific compounds. For example, lithium hydroxide is cheaper to produce from mineral ores than from brine concentrates.[41] The lower price results from not needing to isolate lithium carbonate before yielding lithium hydroxide. By contrast, brine concentrates yield lithium carbonate at lower prices than mineral ores. Lithium hydroxide is the most used intermediary lithium compound for creating battery cathodes.[42] Lithium chloride is further refined to create pure lithium metal or related compounds used in the electrolyte solutions, which will be discussed further in the refined lithium section.

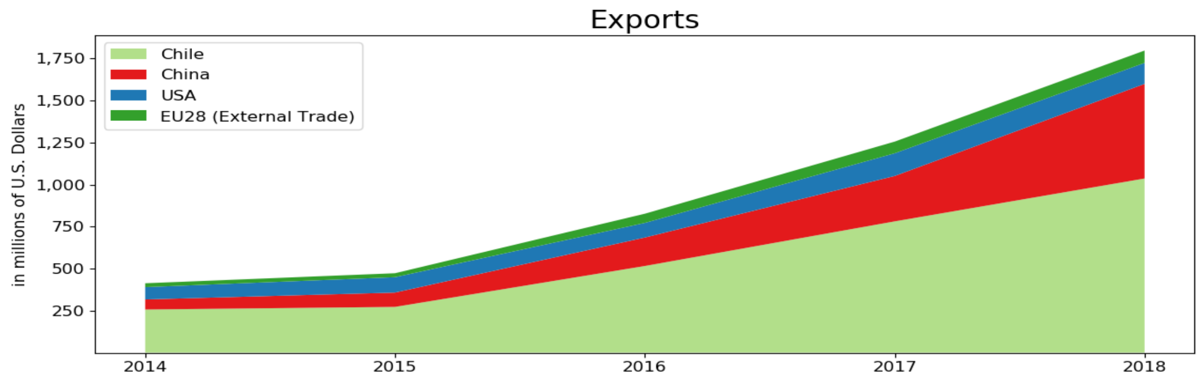
Production information for processed lithium chemicals is not publicly available. Export trade data suggest China and Chile are the largest producers of processed lithium chemicals (figure 10), and that the volume of exports trade from both countries is increasing (see table 5). Chile and China produce lithium from different supply chains. Chilean-processed lithium chemicals are sourced from brine deposits located in Chile. The principle resulting form is lithium carbonate. Chile has increased their exports of processed lithium chemicals, but not as quickly as China. Chinese-processed lithium chemicals are principally sourced from Australian mineral ores. These ores are processed in China, where the value-added activities are occurring as well as the downstream incorporation of these battery materials. The centrality of China in the lithium GVC stems from the aggressive growth of Chinese firms that have developed large capacity in anticipation of demand for lithium, as projected by Chinese industrial policy.[43] Several Australian firms that are working to develop capacity to process ores into lithium hydroxide in Western Australia.[44]

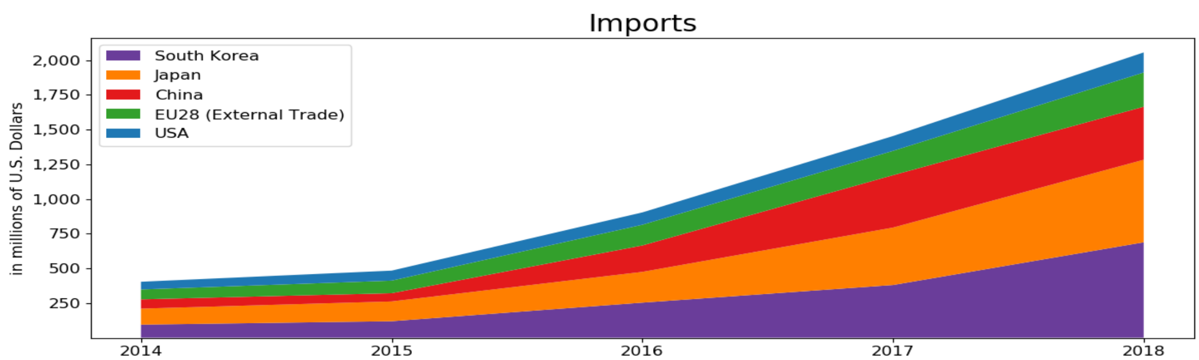
Trade: Processed Lithium Chemicals

Since 2014, trade in processed lithium chemicals (raw stage 2, HS 2836.91 and 2825.20) has increased substantially—figure 10 shows the change in global exports and imports of processed lithium chemicals.[45] The trade data shows an expansion in exports from Chile and China as well as an increase in imports by South Korea and Japan. South Korea and Japan remain the two largest import destinations, but imports of processed lithium chemicals (raw stage 2) also increased for China, the EU and the United States. Table 4 presents a breakdown of the bilateral trade between Chile and South Korea, which is predominantly lithium carbonate. The bilateral trade relationship between Chile and South Korea increased during 2014-18, as South Korea's share of Chile's exports rose from 27.4 percent to 39.2 percent.

[41] Azevedo et al., "Lithium and Cobalt: A Tale of Two Commodities," June 2018.
[42] Cathodes are the negative electrode where electrons leave a battery. In rechargeable batteries, electrons enter a battery through the cathode and are stored in the anode. Azevedo et al, "Lithium and Cobalt: A Tale of Two Commodities," June 2018; and Sherwood, "How Lithium-rich Chile Botched a Plan to Attract Battery Makers," July 17, 2019.
[43] Burton, "Australia Government Launches Strategy to Develop Itself as Battery...," December 11, 2018.
[44] Lynch, "WA cashes in on lithium boom as work begins on world's largest lithium refinery," March 28, 2019.
[45] The trade data does not differentiate whether exports are produced in a country or if products are re-exported. The United States and the European Union produce all forms of processed lithium chemicals and refined lithium compounds covered in this paper.

Figure 10 Global exports and imports of raw stage 2 lithium products (HS 2836.91 and 2825.20)





Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; Graphic developed by USITC staff.
Note: Official trade statistics under subheadings 2825.20 and 2836.91 of the global Harmonized System (HS) of tariff classifications. Discrepancies in import and export values are likely due to reporting issues in the Global Trade Atlas. Export figures are based on “mirror data,” which are derived using export statistics from partner countries’ import data. The exports graph above excludes Argentinian exports of raw stage 2 lithium. The decision to exclude Argentina was a result of Argentinian exports decreasing from $197 million to $47 million over 2017–18. The decline in Argentinian exports in 2018 is attributable to lower commodity prices and the implementation of an export tax on lithium minerals. Limited, Orocobre. “Temporary Argentina Tax Changes,” accessed July 3, 2020. https://www.prnewswire.com/news-releases/temporary-argentina-tax-changes-300706849.html.

Table 4 Chile’s exports of processed lithium chemicals (lithium Raw Stage 2, HS 2836.91 and 2825.20) to the world and South Korea, by value (in millions of U.S. dollars)

Year	Exports to South Korea	Total exports	South Korea's share of the total
2014	70.4	256.8	27.4
2015	86.3	272.4	31.7
2016	147.6	515.9	28.6
2017	237.9	781.4	30.4
2018	406.8	1,036.5	39.2

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019.

Market Profile: Processed Lithium Chemicals from Chile

Chile is the second largest global producer of lithium (table 2), which it produces entirely from brine deposits. Brine deposits historically supplied most of the global demand for lithium. Firms located in

Chile are significant processors of lithium chemicals, primarily lithium carbonate.[46] Chilean authorities have sought to develop downstream lithium industries to convert lithium carbonate into LIB components, and there is production of lithium hydroxide by Sociedad Química y Minera (SQM) at the Salar de Carmen.[47] However, the majority of lithium produced in Chile continues to be lithium carbonate.[48]

Over the last 5 years, Chile has principally exported lithium carbonate to South Korea, Japan, and China. Since 2014, the Chilean lithium industry has not expanded as quickly as competitors in Australia and China have.[49] Specifically, Chilean production of lithium in terms of pure lithium content has increased by 4,500 metric tons (39.1 percent) from 2014 to 2018, which is minor compared to Australia's roughly quadrupled increased output (see table 4 and the Australian case study). The challenge facing the Chilean industry involves increasing the output of low-priced lithium minerals and developing the capacity to convert these minerals into lithium hydroxide.[50]

The most significant producers of lithium in Chile are SQM and Albemarle.[51] SQM is a publicly listed company headquartered in Santiago, Chile. Most of SQM's operations are in Chile, but the company is pursuing a joint venture in Australia. Albemarle is headquartered in the Charlotte, North Carolina, and operates lithium extraction and processing plants throughout the world. In Chile, Albemarle operates brine extraction operations and a chemical refinement plant.[52]

Chinese lithium companies are seeking to grow their ownership stake in South American lithium producers.[53] Tianqi and other Chinese companies seek to invest in lithium extraction operations to prevent supply constraints, especially in Chile.[54] In April 2019, Tianqi Lithium Corporation ("Tianqi") acquired a 23.77 percent stake in SQM valued at $4.1 billion.[55] Despite these supply shortage concerns, SQM recently delayed expansion plans by two years due to the lower commodity prices.[56]

In 2016, Chilean authorities sought to entice downstream lithium consuming industries to establish operations in Chile by offering a low cost supply of lithium.[57] The terms of the agreement established that the Chilean authorities would authorize Albemarle to more than triple production.[58] Albemarle

[46] For more information on how brine deposits are processed, see figure 6. Sherwood, "Chile, Once the World's Lithium Leader, Loses Ground to Rivals," May 30, 2019.
[47] SQM, "Lithium Hydroxide," accessed August 9, 2019.
[48] Dempsey and Hume, "SQM's lithium mine expansion suffers setback after court ruling," December 30, 2019.
[49] Jaskula, "Mineral Commodity Summary: Lithium," January 2020.
[50] Dave Sherwood, "How Lithium-Rich Chile Botched a Plan to Attract Battery Makers." July 17, 2019.
[51] Scheyder, "Albemarle Touts New Project to Boost Its Chilean Lithium Output By...," May 09, 2019.
[52] Albemarle, "Chile," accessed September 26, 2019.
[53] Laing, "China's Tianqi Says Stake in Chile Lithium Miner SQM Good for Both Firms," December 9, 2018.
[54] Scheyder, "Tianqi Says Happy 'for Now' with Stake in SQM: President," June 10, 2019; and Laing, "China's Tianqi Says Stake in Chile Lithium Miner SQM Good for Both Firms," December 9, 2018.
[55] Cambero, "China's Tianqi Agrees Truce in Battle over Chilean Lithium Miner SQM," April 11, 2019.
[56] Dave Sherwood, "Chile Lithium Producer SQM Delays Atacama Expansion amid Price Slump," May 23, 2019; and Thompson, "Tianqi Puts Brakes on Landmark WA Lithium Plant Expansion," September 10, 2019.
[57] Cambero, "Chile Launches Tender for Value-added Lithium Projects," March 25, 2019.
[58] "Albemarle granted permit to increase lithium brine extraction rates in Chile and enters into MOU with Chilean Government for 27-year lithium quota", Albemarle, February 1, 2020.

would then provide approximately 25 percent of the new lithium production capacity to several joint ventures at low costs. These joint ventures would produce downstream battery components in Chile.

However, these efforts are reportedly unraveling due to stagnating lithium production, unmet supply agreements, and a lack of lithium hydroxide conversion capacity in Chile.[59] Two separate joint venture projects to manufacture battery parts in Chile were cancelled.[60] The first instance was a joint venture between Samsung SDI, POSCO, and Albemarle that announced its exit from Chile in June 2019.[61] The second instance was a joint venture between Molymet and Fulin Transportation group that terminated plans to produce LIB components in Chile in July 2019.[62] The stated reasons both joint ventures were halted was due to a failure to provide the discounted lithium materials and a lack of lithium hydroxide, which is not made by Albemarle in Chile.

Refined Lithium Compounds

Following processing, lithium compounds may require further transformation to yield the desired refined lithium compound. Refined lithium compounds are forms of lithium that are ready for end-use, such as pure lithium metal, alloys containing lithium, or electrolyte solutions. Refined lithium is traded internationally under the following HS6 subheadings 2826.90, 2827.39, and 2805.19 (table 1).

Lithium alloys comprise the cathode materials used in EV LIBs, while lithium chloride is an input into electrolyte solutions.[63] Electrolyte solutions are the medium in which lithium ions move between the anode and cathode of LIBs in order to store or expend electrical energy. Electrolyte solutions are composed of lithium salt, organic solvents, and other additives. Lithium hexafluorophosphate (LiPF6 or LPF) is the most commonly used lithium concentrate found in the electrolyte of LIBs.[64] The process for producing LPF is a trade secret, but the basic inputs are lithium, fluorine, and phosphate acid.[65] LPF is traded internationally under HS 2826.90.[66]

Production data information for refined lithium compounds is not publicly available. However, analyst estimates of China's share of global lithium refining capacity range from 50 percent to 89 percent.[67] The estimates for China's share of global lithium processing capacity vary widely due to the lack of publicly available information as well as differing product definitions.

Trade data shows a significant decrease in the value of refined lithium compounds being traded internationally (figure 11). The decline in value shown by the trade data suggests the international trade

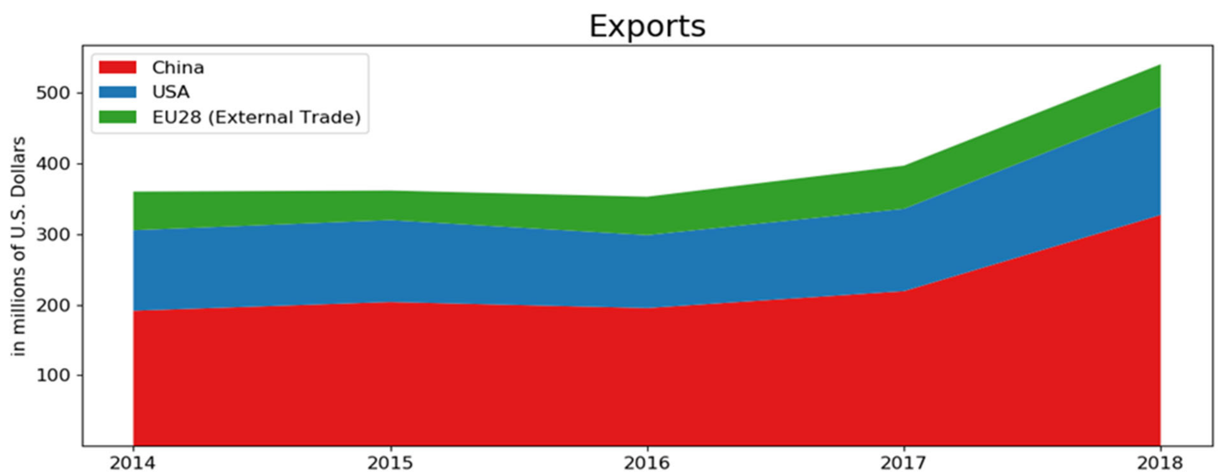
[59] Sherwood, "How Lithium-rich Chile Botched a Plan to Attract Battery Maker," July 17, 2019.
[60] Sherwood, "How Lithium-rich Chile Botched a Plan to Attract Battery Maker," July 17, 2019.
[61] Sherwood and Chung, "South Korea's POSCO Drops Plans for Chilean Battery Material Plant," June 21, 2019.
[62] Sherwood, "Molymet Drops Plans for Battery Parts Factory in Chile," July 13, 2019.
[63] Unalloyed lithium metals are used for non-rechargeable batteries; however, pure lithium metal is not used in EV LIBs.
[64] "Stable Supply of a Key Material of Power Sources for Advanced Equipment," Sumitomo Corporation in Europe, February 2017.
[65] "Stable Supply of a Key Material of Power Sources for Advanced Equipment," Sumitomo Corporation in Europe, February 2017.
[66] American Elements, "Lithium Hexafluorophosphate," June 13, 2017.
[67] Sanderson, "Electric Cars: China Powers the Battery Supply Chain," May 22, 2019; and Willis et al, "Australia's Opportunity in the Lithium Battery Boom," Future Smart Strategies, January 30, 2018.

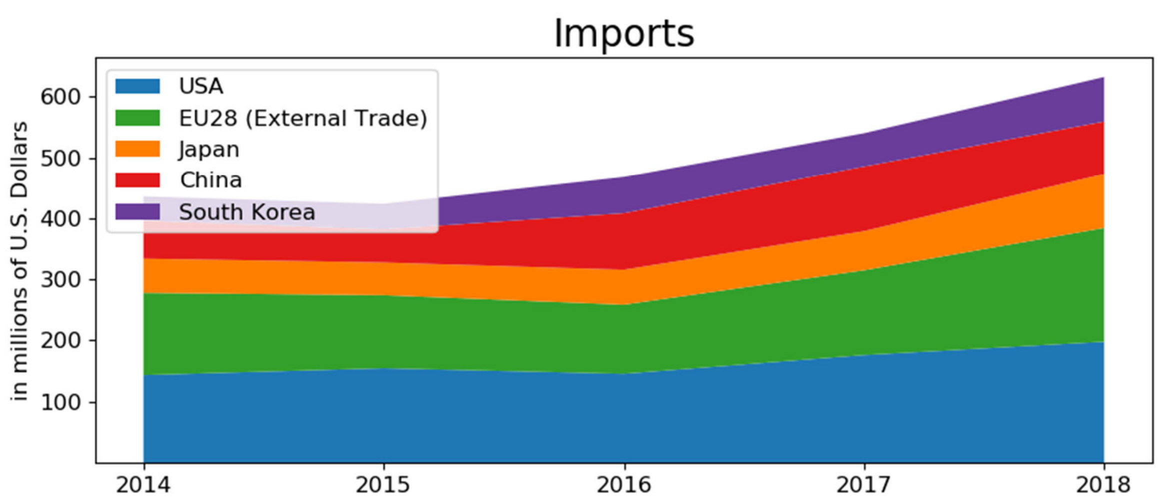
of refined lithium compounds markedly declines despite the increase in average unit values that occur with the various refining activities. These combined trends suggest that countries that convert processed lithium chemicals into refined lithium compounds domestically consume the refined lithium compounds in the production of LIBs.

Trade: Refined Lithium Compounds

The value of trade for refined lithium products (HS 2826.90 and 2805.19) is significantly lower than for unprocessed and processed lithium compounds (HS 2530.90 and 2825.20) (figure 11). The lower trade values suggest that countries that import unprocessed and processed lithium compounds tend to convert them into refined lithium. The refined lithium is then consumed domestically to create LIB components, rather than exported. For example, China is the largest processor of refined lithium, but it exports relatively low values of the product. Presumably, the refined lithium is being consumed in China to produce LIBs. Like China, Japan and South Korea are large importers of raw lithium products and large producers of refined lithium, but not large refined lithium exporters. Japan and South Korea are not included among the largest exporters despite being significant importers of raw stage 2 lithium products (HS 2836.91 and 2825.20). As such, Japan and South Korea are also likely consuming most of their output of refined lithium to produce LIB components. In addition to China, the United States and the EU are the leading exporters of refined lithium compounds. The United States and the EU are the largest destination markets, but Japan, China, and South Korea are also significant importers of refined lithium products.

Figure 11 Global Exports and Imports of refined lithium products (HS 2826.90 and 2805.19)





Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; graphic developed by USITC staff.
Note: Official trade statistics under subheadings 2805.19, 2826.90, and 2827.39 of the global Harmonized System (HS) of tariff classifications. The HS codes examined do not exclusively pertain to lithium compounds used in EVs. Discrepancies in import and export values are likely due to reporting issues in the Global Trade Atlas. Export figures are based on "mirror data," which are derived using export statistics from partner countries' import data.

Table 5 China's exports of refined lithium compounds (HS 2826.90 and 2805.19) to the world and USA, by value (in millions of U.S. dollars)

Year	Exports to USA	Total Exports	USA's share of the total
2014	23.6	191.3	12.3
2015	22.8	203.7	11.2
2016	18.2	195.2	9.3
2017	36.6	219	16.7
2018	58.8	326.9	18.0

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019.

Market Profile: Refined Lithium Compounds from China

China is the largest processor and refiner of lithium compounds, such as lithium chloride and lithium metal. China is also the largest exporter, with most of its exports going to the United States and smaller volumes to Japan and South Korea. However, given China's significant volume of LIB production, most lithium compounds produced in the country are believed to be domestically consumed to produce batteries and not exported for consumption abroad.[68] In recent years, private Chinese firms have increased production of lithium materials and batteries in China and acquired major equity stakes in foreign lithium extraction operations. The growth of these private firms is a result of market preferences favoring aggressive growth and the receptiveness by business leaders to chase after potential opportunities identified by industry policy.[69] These efforts align with policy goals set by the Chinese government, such as those elaborated in *Made in China 2025*—an economic plan by China's State Council.[70] Incentives by the Chinese government focus on subsidizing automotive manufacturers to electrify vehicles and motivating consumers to purchase EVs.[71]

In May 2015, the government of China announced a new program called *Made in China 2025*, which calls for Chinese domestic firms to acquire significant domestic and global market share within ten advanced-technology industries by the year 2025. The initiative calls for Chinese domestic firms to have 70 percent of the Chinese market for EVs and plug-in hybrids by 2020, and 80 percent by 2025, as well as for two Chinese firms to be among the top ten largest new-energy vehicle manufacturers in the world.[72] These EV production goals rely upon a massive increase in LIB production. In 2018, Chinese firms produced 134.5 gigawatt hours of LIBs, accounting for or 61 percent of global LIB production capacity in 2018.[73] Analysts forecast that Chinese production of LIBs will reach 405 gigawatt hours in 2023 or 62 percent of forecasted global battery production capacity in 2023.[74]

Sichuan Tianqi Lithium ("Tianqi") and Ganfeng are the two largest Chinese lithium refining firms and among the largest lithium companies in the world.[75] In fact, Tianqi is the world's single largest refiner of lithium materials and produces lithium metal and certain battery metal alloys from unprocessed and processed lithium materials. Battery manufacturers consume these metals and alloys to produce cathodes. In March 2019, Tianqi announced plans to become a vertically integrated LIB producer.[76] Ganfeng is already an integrated battery producer, and internally consumes the refined lithium

[68] Desjardins, "Battery Megafactory Forecast: 400% Increase in Capacity to 1 TWh by 2028," October 19, 2018.
[69] Sanderson, "Electric Cars: China Powers the Battery Supply Chain," May 22, 2019.
[70] "China to Invest Big in 'Made in China 2025' Strategy," October 12, 2017.
[71] Kennedy, "China's Risky Drive into New-Energy Vehicles," accessed July 3, 2020; https://www.csis.org/analysis/chinas-risky-drive-new-energy-vehicles; and Lichun and Wei, "China Extends Electric Vehicle Incentives by Two Years," accessed July 3, 2020. https://www.caixinglobal.com/2020-04-01/china-extends-electric-vehicle-incentives-by-two-years-101537037.html.
[72] *Economist Intelligence Unit*, "The Road Ahead: China's New-Energy Vehicles," October 4, 2017.
[73] Desjardins, "Battery Megafactory Forecast: 400% Increase in Capacity to 1 TWh by 2028," October 19, 2018.
[74] Desjardins, "Battery Megafactory Forecast: 400% Increase in Capacity to 1 TWh by 2028," October 19, 2018.
[75] Albemarle, 2018 Annual Report, February 27, 2019.
[76] Liuxi and Kirton, "Lithium Mine Giant Tianqi Extends Reach into Downstream Battery Production," March 13, 2019.

materials it produces to create batteries. Ganfeng has contracts to supply lithium-ion batteries to major automobile producers, such as Volkswagen.[77]

To support the country's growing lithium materials and battery production, lithium extraction operations in China increased 5,700 metric tons (348 percent) from 2014 to 2018.[78] The Chinese lithium extraction industry has mineral and brine deposits in Qinghai, Yunnan, and Sichuan provinces and the Tibet autonomous region.[79] Chinese authorities have actively sought to expand production capacity in China to wean the country from being dependent on imported lithium inputs.[80]

However, despite increased domestic lithium production, Chinese lithium processors/refiners remain dependent upon imports of lithium compounds from Australia and to a lesser extent Chile, and Argentina.[81] Imports are processed and/or refined in China and may be exported or consumed domestically. Chinese lithium firms have actively sought to acquire and develop partnerships with foreign producers of raw lithium materials (HS 2530.90) and unprocessed lithium chemicals (HS 2836.91 and 2825.20) to ensure supply. Both Tianqi and Ganfeng own and operate mines or brine extraction in Australia, Chile, Argentina, and China.[82] For example, China's Tianqi lithium holds a 51 percent stake in Lithium's Greenbushes mine. [83] In July 2018, Tianqi's board voted to expand production of the Greenbushes mine.[84] In December 2018, Tianqi purchased a 23.8 percent stake in Sociedad [85] y Minera ("SQM"), from a holding company.[86] Additionally, Ganfeng holds a 50 percent stake in the Cauchari-Olaroz brine in Argentina.[87]

Trade Analysis

Six different HS numbers capture trade in lithium: unprocessed (raw stage 1, HS 2530.90), processed (raw stage 2, HS 2836.91 and 2825.20), and refined (HS 2805.19, 2827.39, and 2826.90). The 2018 global export unit price for unprocessed lithium from Australia was $0.34 per kilogram and the processed lithium export unit price from Chile was $13.37. The trade data presented earlier suggest that there are two unique lithium value chains. The first consists of unprocessed lithium minerals exported from Australia to China for processing refinement and battery manufacturing.[88] The second is composed of processed lithium chemicals exported from Chile into South Korea, Japan, and China for refinement and battery manufacturing. Unfortunately, there is a lack of comparable value-added data for the different stages and locations of production across the lithium GVC. However, the available information suggests

[77] "Volkswagen Group Secures Lithium Supplies." Volkswagen Newsroom, April 5, 2019.
[78] Jaskula, "Mineral Commodity Summary: Lithium," January 2020.
[79] Wanli, "'World-class' Deposit of Lithium Found, Could Ease Reliance on Imports," June 5, 2019.
[80] Jaskula, "Mineral Commodity Summary: Lithium," January 2020.
[81] Wanli, "'World-class' Deposit of Lithium Found, Could Ease Reliance on Imports," June 5, 2019.
[82] Jamasmie, "China's Ganfeng Grabs SQM's Stake in Argentinean Lithium Project." August 14, 2018.
[83] Talison Lithium, "About," accessed July 23, 2019.
[84] Jamasmie, "Tianqi Goes Ahead with $382-million Greenbushes Lithium Mine Expansion," July 25, 2018.
[85] De la Jara, "Tianqi Buys Stake in Lithium Miner SQM from Nutrien for $4.1 Billion," December 3, 2018.
[86] De la Jara, "Tianqi Buys Stake in Lithium Miner SQM from Nutrien for $4.1 Billion," December 3, 2018.
[87] De la Jara, "Tianqi Buys Stake in Lithium Miner SQM from Nutrien for $4.1 Billion," December 3, 2018.
[88] China's exports to the United States are a relevant share of bilateral trade of refined lithium, however, these are not recognized as those used in LIBs; the unit price per kilogram in 2018 of products in HS 2805.19 were $61.28, HS 2826.90 were $4.33, and HS 2827.39 were $4.26 (IHS Markit, Global Trade Atlas, accessed January 12, 2020).

that China is capturing the largest share of value-added with its leading role in lithium refining. As previously discussed, the biggest actors in China are private industry participants that expanded quickly with motivation stemming by Chinese industry policy.

Trade: GVC Measures

Measurements to evaluate where countries reside in the GVC for certain intermediate goods (before their integration in a final good) are available based on trade data.[89] Specifically, several trade-data based indicators are available that reveal the importance of individual countries upstream—from mining to refining—as products cross borders through the EV LIB value chain. These indicators do have shortcomings, mostly due to the broad HS categories involved, providing a wider range of related products than the intermediate goods of interest.[90] The trade-based GVC measures used here are the Coverage Ratio, Grubel-Lloyd index, and Revealed Comparative Advantage (RCA).[91]

The Coverage Ratio is a broad measure of a country's position in the value chain. This ratio compares the country's imports with its exports. Lower values tend to indicate that a country is upstream or at the beginning of the value chain; conversely, higher values indicate that a country is downstream or near the end of the value chain. The very low coverage ratios presented in table 5 for Australia and Chile confirm that these countries reside upstream in the lithium GVC and have advantages in the production and export of unprocessed and processed lithium materials. Japan, Korea, China and the United States are positioned downstream in the GVC. The Coverage Ratios for Japan and Korea are relatively high because, in general, they import much more lithium than they export.

Table 6 Lithium measures (HS 2530.90, 2836.91, 2825.20, 2826.90, and 2805.19), selected countries, 2018, percent

Country	Coverage ratio: imports to refined exports	Lithium exports to all Goods exports	Lithium imports to all Goods imports	Lithium trade to All goods trade	Relative importance of lithium trade	Grubel-Lloyd Index	Revealed comparative Advantage
Australia	1.8	0.5	0.0	0.2	0.1	0.0	24.6
Chile	0.4	1.4	0.0	0.7	0.4	0.0	75.9
China	162.7	0.0	0.1	0.1	0.0	0.8	2.5
Japan	1,649.9	0.0	0.1	0.1	0.0	0.1	0.3
Korea, Republic of	1,458.9	0.0	0.2	0.1	0.1	0.1	0.5
United States	79.4	0.0	0.0	0.0	0.0	0.9	1.3

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; USITC staff calculations.
Note: For a breakdown of the value percentages by commodity see Appendixes 1-3.
[a] Additional calculations on the individual phases of lithium trade data are in Appendix A.

[89] Other GVC indicators, such as TiVA are available at the industry, rather than intermediate product level. They also exclude relevant countries, such as DRC. OECD, "Trade in Value Added," https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm, 2019 (accessed December 9, 2019).
[90] World Customs Organization (WCO). (n.d.). *What is the Harmonized System?* Retrieved December 11, 2019, from http://www.wcoomd.org/en/topics/nomenclature/overview/what-is-the-harmonized-system.aspx.
[91] Ahmad et al, "Indicators on global value chains: A guide for empirical work," July 6, 2017.

The Grubel-Lloyd Index (GL) provides country-level information on intra-material trade.[92] A higher index value (closer to 1.0) reflects more trade. At 1.0, a country would be exporting as much of the good as it imports, suggesting it may be involved in multiple stages of production. Conversely, if the value is zero, the country either only exports or imports the good. Lower percentages are likely outcomes for countries involved in lithium refining and LIB manufacturing. Notably, when a country's commodities cross borders many times, some double counting may occur in measures that combine imports and exports for the GVC phases.[93] The Grubel-Lloyd measures on lithium trade presented in table 5 show that Australia and Chile had very low scores, indicating they are large raw lithium exporters, do not import large volumes, and have low levels of intra-material trade; this finding is consistent with the qualitative analysis presented earlier. Japan and Korea's imports are significantly higher than their exports, reflecting some lithium refining and consumption. China and the United States had scores that were significantly higher (approaching unity) than the other countries, implying significant two-way trade. As noted earlier, China's industry has sizeable imports of unprocessed lithium minerals and significant exports of processed lithium chemicals and refined lithium compounds.

The RCA index reveals the intensity with which a country exports a product.[94] The RCA is calculated as a proportion of the country's lithium exports to its total exports, divided by the proportion of global lithium exports to total world exports. This score is dependent on the country's lithium exports to all goods exports and how it compares with world lithium exports to world total goods exports. RCA results (table 5) that are greater than unity show a country's comparative commodity advantage and less than unity shows a comparative disadvantage. Korea and Japan had the lowest scores in the revealed comparative advantage, which can be attributed to a dependence on imported lithium carbonate; they export less lithium as a share of all export than does the rest of the world. China and the United States have advantages beyond unity; on lithium exports, these countries are above the norm, but not as high as Chile and Australia. The results of the comparative analysis indicate that Chile and Australia have substantial advantages in lithium exports; in particular, these countries export large values in raw and processed lithium.

The trade based GVC measures confirm the earlier descriptive analysis, that Australia and Chile have advantages upstream and are involved in producing unrefined materials. China and the United States have higher intra-materials lithium trade, as they both import and export lithium across the GVC. Japan, Korea, the United States, and China are relatively downstream in the production process; these countries are all involved in refining and consuming refined lithium (e.g., LIB manufacturing).

[92] A higher index value (closer to 1.0) reflects more trade. At 1.0, a country would be exporting as much of the good as it imports, suggesting it may be involved in multiple stages of production. Conversely, if the value is zero, the country either only exports or imports the good. Lower percentages are likely outcomes for countries involved in lithium refining and LIB manufacturing.

[93] If a country imports the raw product and then exports the refined product, those materials are counted twice when adding them to calculate total trade for that material.

[94] Values greater than unity reveals a comparative commodity advantage, exporting more than its "fair" share. Conversely, values less than unity, the country has a comparative disadvantage, exporting less than its "fair" share in world trade.

Conclusion

Few countries have economically viable endowments of the upstream raw materials that supply the lithium GVC. Due to the cost of mining and refining steps specific to ores vs. brine concentrates, two different GVCs have emerged. Lithium-rich ores tend to be sent from Australia to China for processing. Brine concentrates in the form of processed lithium chemicals are principally sent from Chile to Japan, South Korea, and China. China holds a dominant role in the downstream processing and refining processes, which are where much of the value-added occurs. As a result, China is capturing the largest shares of global value-added, despite lacking in resource endowment. Most of the Chinese lithium is being internally consumed to power Chinese EVs and other devices that rely on LIBs. Exports of Chinese LIBs (under HTS6 subheading 8507.60) total $13 billion in 2019 with the largest destination markets being the United States, Germany, South Korea, India, and Vietnam.[95] The Chinese government is actively pursuing a large global position in the production of LIBS and LIB materials, in part, to support its EV production goals. Furthering these goals, Chinese companies have been active in acquiring equity positions in global producers of the raw materials to ensure a steady supply of lithium for its downstream industries.

[95] HTS-6 subheading 8507.60 does not distinguish between LIBs used in electronic devices from those used in electric vehicles.

Bibliography

Ahmad, N. et al. "Indicators on global value chains: A guide for empirical work." *OECD Statistics Working Papers, 2017/08, OECD Publishing, Paris.* July 6, 2017, http://dx.doi.org/10.1787/8502992f-en.

Albemarle. 2016. *Albemarle granted permit to increase lithium brine extraction rates in Chile and enters into MOU with Chilean Government for 27-year lithium quota.* February 1. Accessed January 23, 2020. https://www.prnewswire.com/news-releases/albemarle-granted-permit-to-increase-lithium-brine-extraction-rates-in-chile-and-enters-into-mou-with-chilean-government-for-27-year-lithium-quota-300213257.html.

Albemarle. 2019. *Chile.* September 26. https://www.albemarle.com/locations/south-america/chile.

Albemarle. n.d. *Lithium Air Conditioners, Gas, & Air Treatment.* Accessed August 9, 2019. https://www.albemarle.com/businesses/lithium/markets--applications/air-conditioners--gas--air-treatment.

Albemarle. n.d. *Lithium Enamels and Ceramics.* Accessed August 9, 2019. https://www.albemarle.com/businesses/lithium/markets--applications/enamels--ceramics.

Albemarle. n.d. *Lithium Rubber and Plastics.* Accessed August 9, 2019. https://www.albemarle.com/businesses/lithium/markets--applications/rubber--plastics.

American Elements. 2017. *Lithium Hexafluorophosphate.* June 13. https://www.americanelements.com/lithium-hexafluorophosphate-21324-40-3.

Anderson, Thomas, and Torbörn Fredriksson. 2000. "Distinction between Intermediate and Finished Products in Intra-firm Trade." *International Journal of Industrial Organization* 773-792. https://doi.org/10.1016/S0167-7187(98)00041-1.

Andreff, Wladimir. 2009. "Outsourcing in the New Strategy of Multinational Companies: Foreign Investment, International Subcontracting and Production Relocation." *Papeles de Europa* 5-34. https://www.researchgate.net/publication/28250237/download.

Argonne National Laboratory. 2018. *BatPac: A Lithium-Ion Battery Performance and Cost Model for Electric-Drive Vehicles.* June 28. http://www.cse.anl.gov/batpac/index.html.

Australian Trade and Investment Commission. 2018. *The Lithium-Ion Battery Value Chain.* December. https://www.austrade.gov.au/ArticleDocuments/5572/Lithium-Ion Battery Value Chain report.pdf.aspx.

Azevedo, Marcelo, Nicolò Campagnol, Toralf Hagenbruch, Ken Hoffman, Ajay Lala, and Oliver Ramsbottom. 2018. *Lithium and Cobalt: A Tale of Two Commodities.* June. https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-and-cobalt-a-tale-of-two-commodities.

Baldwin, Richard, and Anthony J. Venables. 2013. "Spiders and Snakes: Offshoring and Agglomeration in the Global Economy." *Journal of International Economics* 245–54.

Burton, Melanie. 2018. *Australia Government Launches Strategy to Develop Itself as Battery Hub.* December 11. https://www.reuters.com/article/us-australia-batteries/australia-government-launches-strategy-to-develop-itself-as-battery-hub-idUSKBN1OA0GS.

Burton, Melanie. 2018. *Australian Miners Steam Ahaead with Lithium Exploration.* August 9. https://www.reuters.com/article/us-australia-mining/australian-miners-steam-ahead-with-lithium-exploration-idUSKBN1KV09F.

Cambero, Fabian. 2019. *Chile Launches Tender for Value-added Lithium Projects.* March 25. https://www.reuters.com/article/us-chile-lithium-sqm/chile-launches-tender-for-value-added-lithium-projects-idUSKCN1R621L.

Cambero, Fabian. 2019. *China's Tianqi Agrees Truce in Battle over Chilean Lithium Miner SQM.* April 11. https://www.reuters.com/article/us-sqm-tianqi-lithium/chinas-tianqi-agrees-truce-in-battle-over-chilean-lithium-miner-sqm-idUSKCN1RN2B0.

China Energy Storage Alliance. 2016. *Nine Updates on China's 2016 Energy Storage Industry.* September 29. http://en.cnesa.org/featured-stories/2016/9/27/nine-updates-on-chinas-2016-energy-storage-industry.

Chung, Jane, and Joyce Lee. 2017. *Asian Battery Makers Eye Nickel Top-up as Cobalt Price Bites.* August 3. https://www.reuters.com/article/us-southkorea-battery-cobalt/asian-battery-makers-eye-nickel-top-up-as-cobalt-price-bites-idUSKBN1AJ0S8.

Coffin, David, and Jeff Horowitz. 2018. "The Supply Chain for Electric Vehicle Batteries." *Journal of International Commerce and Economics.* https://www.usitc.gov/sites/default/files/publications/332/journals/the_supply_chain_for_electric_vehicle_batteries.pdf.

Council of Supply Chain Management Professionals. n.d. *CSCMP Supply Chain Management Definitions and Glossary.* Accessed November 8, 2019. https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921.

De la Jara, Antonio. 2018. *Tianqi Buys Stake in Lithium Miner SQM from Nutrien for $4.1 Billion.* December 3. https://www.reuters.com/article/us-chile-tianqi-lithium/tianqi-buys-stake-in-lithium-miner-sqm-from-nutrien-for-4-1-billion-idUSKBN1O217F.

Dempsey, Harry, and Neil Hume. 2019. *Reuters.* December 30. https://www.ft.com/content/0be2e7c0-2afd-11ea-a126-99756bd8f45e.

Desjardins, Jeff. 2019. *Battery Megafactory Forecast: 400% Increase in Capacity to 1Wh by 2028.* March 12. https://www.visualcapitalist.com/battery-megafactory-forecast-1-twh-capacity-2028/.

DeYoung, John H., Jr., Robert R Seal, and Dwight C Bradley. 2017. *Critical Mineral Resources of the United States - Economic and Environmental Geology and Prospects for Future Supply.* December 19. https://pubs.er.usgs.gov/publication/pp1802.

Escaith, Hubert. 2017. *Accumulated Trade Costs and their Impact on Domestic and International Value Chains.* Working Paper, Washington DC: World Bank. http://www.worldbank.org/en/topic/trade/publication/global-value-chain-development-report-measuring-and-analyzing-the-impact-of-gvcs-on-economic-development.

Evarts, Eric. 2019. *GM Wins US Grant to Develop Solid-State Batteries.* August 27. https://www.greencarreports.com/news/1124702_gm-wins-us-grant-to-develop-solid-state-batteries.

Facada, Martim. 2019. *Mineral Resources' Mount Marion Spodumene Production down in First Quarter.* May 1. https://www.metalbulletin.com/Article/3871889/Mineral-Resources-Mount-Marion-lithium-spodumene-production-down-in-first-quarter.html.

Feenstra, Robert C, and Gordon H Hanson. 1996. *Globalization, Outsourcing, and Wage Inequality.* Working Paper, Cambridge: National Bureau of Economic Research.

Frederick, Stacey. 2014. *Combining GVC and Global Industrial Organization Approaches.* Presentation to the Conference of the Measurement of International Trade adn Economic Globalization, Aguascalientes: United Nation Statistics Division. http://unstats.un.org/unsd/trade/events/2014/mexico/documents/session3/2014-09-29_Frederick,%20Stacey_Combining%20GVC%20and%20global%20I-O%20approaches.pdf.

Frederick, Stacey. 2010. *Development and Application of a Value Chain Research Approach to Understand and Evaluate Internal and External Factors and Relationships Affecting Economic Competitiveness in the Textile Value Chain.* PhD Dissertation, Raleigh: North Carolina State University. https://repository.lib.ncsu.edu/handle/1840.16/6190.

Goldie-Scot, Logan. 2019. *A behind the Scenes Take on Lithium-Ion Battery Prices.* March 5. https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/.

Grossman, David. 2019. *Lithium Metal Could Soon Replace Lithium Ion in Batteries.* August 29. https://www.popularmechanics.com/cars/hybrid-electric/a28859683/lithium-metal-replace-lithium-ion-batteries/.

Grossman, Gene M., and Esteban Rossi-Hansberg. 2006. “The Rise of Offshoring: It's Not Wine for Cloth Anymore.” *Princeton University.* https://www.princeton.edu/~erossi/RO.pdf.

Hamer, Ashley. 2019. *4 Up-and-Coming Batteries That Could Overtake Lithium-Ion.* January 22. https://curiosity.com/topics/4-up-and-coming-batteries-that-could-overtake-lithium-ion-curiosity/.

Henderson, Jeffrey, Peter Dicken, Martin Hess, Neil Coe, and Henry Wai-Chung Yeung. 2002. “Global Production Networks and the Analysis of Economic Development.” *Review of International Political Economy* 436-64. https://doi.org/10.1080/09692290210150842d.

Heppel, George, Daniel Chen, and James Jeary. 2019. *CRU.* August 20. https://www.crugroup.com/knowledge-and-insights/insights/2019/lithium-prices-crash-through-10-000-as-hype-meets-reality/?utm_term=&utm_content=Read%20full%20Insight&utm_campaign=CRU%20Insight%20newsletter%202019%20september&contactID=428088&utm_source=Ade.

Heppel, George, Daniel Chen, and James Jeary. 2019. *Lithium prices crash through $10,000 as hype meets reality.* August 20. https://www.crugroup.com/knowledge-and-insights/insights/2019/lithium-prices-crash-through-10-000-as-hype-meets-reality.

Home, Andy. 2019. *COLUMN-Boom-and-Bust Lithium Market Needs a Pricing Rethink.* June 24. https://www.reuters.com/article/metals-lithium-ahome/column-boom-and-bust-lithium-market-needs-a-pricing-rethink-andy-home-idUSL8N23V4IE.

Huang, Echo. 2018. *China's Making it Super Hard to Build Car Factories that Don't Make Electric Vehicles.* December 19. https://qz.com/1500793/chinas-banning-new-factories-that-only-make-fossil-fuel-cars/.

Hummels, David, Dana Rapoport, and Yi Kei-Mu. 1998. "Vertical Specialization and the Changing Nature of World Trade." *Federal Reserve Bank of New York Policy Review* 79–99. https://www.newyorkfed.org/medialibrary/media/research/epr/98v04n2/9806humm.pdf.

IEA. 2019. "Electric car deployment in selected countries, 2013–2018." Paris.

Irle, Roland. n.d. *The Electric Vehicle World Sales Database.* Accessed August 9, 2019. http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/.

Jacoby, Mitch. 2018. *Flouride-Ion Battery Runs at Room Temperature.* December 10. https://cen.acs.org/materials/energy-storage/Flouride-ion-battery-runs-room/96/web/2018/12.

Jaksula, Brian W. 2020. *U.S. Geological Survey Mineral Commodity Summary.* January.

Jamasmie, Cecilia. 2018. *China's Ganfeng Grabs SQM's Stake in Argentinean Lithium Project.* August 14. http://www.mining.com/chinas-ganfeng-grabs-sqms-stake-argentinean-lithium-project/.

Johnson, Robert C, and Guillermo Noguera. 2012. "Accounting for Intermediates: Production Sharing and Trade in Value Added." *Journal of International Economics* 224-36. https://doi.org/10.1016/j.jinteco.2011.10.003d.

Jones, Lin, Meryem Demirkaya, and Erika Bethmann. 2019. "Global Value Chain Analysis: Concepts and Approaches." *Journal of International Commerce and Economics.* https://www.usitc.gov/journals/jice_home.htm.

Kanellos, Michael. 2016. *Is There Money to be Made in Lithium Mining?* August 29. https://www.forbes.com/sites/michaelkanellos/2016/08/29/is-there-money-to-be-made-in-lithium-mining/#3de1e04c23f3.

Kay, Amanda. 2018. *6 Lithium-ion Battery Types.* July 23. https://investingnews.com/daily/resource-investing/energy-investing/lithium-investing/6-types-of-lithium-ion-batteries/.

Kennedy, Scott. 2018. *China's Risky Dive into New-Energy Vehicles.* November. https://www.csis.org/analysis/chinas-risky-drive-new-energy-vehicles

Kleinert, Jörn. 2003. "Growing Trade in Intermediate Goods: Outsourcing, Global Sourcing, or Increasing Importance of MNE Networks?" *Review of International Economics* 464-82. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=421963.

Koopman, Robert, William Powers, Zhi Wang, and Shang-Jin Wei. 2010. *Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains.* Working Paper, Cambridge: National Bureau of Economic Research. https://www.nber.org/papers/w16426.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei. 2014. "Tracing Value-Added and Double Counting in Gross Exports." *American Economic Review* (American Economic Review) 459-94. https://www.aeaweb.org/articles?id=10.1257/aer.104.2.459.

Kwon, Taehyun, and Jai-Won Ryou. 2015. "Global Value Chains of East Asia: Trade in Value Added and Vertical Specialization." *Asian Economic Journal* 121-43.

Laing, Aislinn. 2018. *China's Tianqi Says Stake in Chile Lithium Miner SQM Good for Both Firms.* December 9. https://www.reuters.com/article/us-chile-tianqi-lithium/chinas-tianqi-says-stake-in-chile-lithium-miner-sqm-good-for-both-firms-idUSKBN1O80JF.

Leni, Brian. 2017. *The Lithium Supply and Demand Story.* January 30. https://www.mining.com/web/lithium-supply-demand-story/.

Lichun, Zheng, and Han Wei. 2020. *China Extends Electric Vehicle Incentives by Two Years.* April 1. https://www.caixinglobal.com/2020-04-01/china-extends-electric-vehicle-incentives-by-two-years-101537037.html.

Lu, Sophie. 2019. *LME-Fastmarkets and the Future of Lithium Pricing.* June 18. https://www.bnef.com/core/insights/20891.

Lynch, Jacqueline. 2019. *WA cashes in on lithium boom as work begins on world's largest lithium refinery.* March 28. Accessed January 23, 2020. https://www.abc.net.au/news/2019-03-28/wa-cashes-in-as-work-begins-on-worlds-largest-lithium-refinery/10950970.

Morris, David Z. 2015. *The era of the electric car promises a lithium mining boom, but new lithium startups are floundering. Here's why.* April 26. https://fortune.com/2015/04/26/lithium-mining/.

Organisation for Co-operation and Development. 2012. *Mapping Global Value Chains.* https://www.oecd.org/dac/aft/MappingGlobalValueChains_web_usb.pdf.

Rauch, James E. 1999. "Networks Versus Markets in International Trade." *Journal of International Economics* 7-35. https://doi.org/10.1016/S0022-1996(98)00009-9.

Reuters. 2019. *Game of Mines.* July 18. https://graphics.reuters.com/ELECTRIC-VEHICLES-METALS/010092JB38P/index.html.

Royal Society of Chemistry. n.d. *Periodic Table: Lithium.* Accessed July 23, 2019. http://www.rsc.org/periodic-table/element/3/lithium.

Samsung SDI. 2016. *The Four Components of a Lithium-Ion Battery.* Accessed January 20, 2020. https://www.samsungsdi.com/column/technology/detail/55272.html?listType=gallery.

Sanderson, Henry. 2019. *Electric Cars: China Powers the Battery Supply Chain.* May 22. https://www.ft.com/content/455fe41c-7185-11e9-bf5c-6eeb837566c5.

Sanderson, Henry. 2019. *Financial Times.* August 22. https://www.ft.com/content/84a2240c-c507-11e9-a8e9-296ca66511c9.

Sanderson, Henry. 2019. *Lithium Hit by Oversupply and Electric Vehicle Subsidy Cuts.* August 26. https://www.ft.com/content/2e5f7e2c-c5c6-11e9-a8e9-296ca66511c9.

Scheyder, Ernest. 2019. *Albemarle Touts New Project to Boost its Chilean Lithium Output by 30 percent.* May 9. https://www.reuters.com/article/us-albemarle-results-electric/albemarle-touts-new-project-to-boost-its-chilean-lithium-output-by-30-percent-idUSKCN1SF1VU.

Scheyder, Ernest. 2018. *FMC Says Lithium Pricing Rising on Strong Electric Car Demand.* August 2. https://www.reuters.com/article/fmc-lithium/fmc-says-lithium-pricing-rising-on-strong-electric-car-demand-idUSL1N1UT0KU.

Scheyder, Ernest. 2019. *Tianqi Says Happy 'For Now' with Stake in SQM: President.* June 10. https://www.reuters.com/article/us-lithium-electric-tianqi-lithium/tianqi-says-happy-for-now-with-stake-in-sqm-president-idUSKCN1TB20K.

Schreffler, Roger. 2017. *Electric Propulsion Gaining Traction in China.* August 3. https://www.wardsauto.com/industry/electric-propulsion-gaining-traction-china.

Shankleman, Jessica, Tom Biesheuvel, Joe Ryan, and Dave Merill. 2017. *We're Going to Need More Lithium.* September 7. https://www.bloomberg.com/graphics/2017-lithium-battery-future/.

Shankleman, Jessica, Tom Biesheuvel, Joe Ryan, and Dave Merrill. 2017. *We're Going to Need More Lithium.* September 7. https://www.bloomberg.com/graphics/2017-lithium-battery-future/.

Sherwood, Dave. 2019. *Chile Lithium Producer SQM Delays Atacama Expansion amid Price Slump.* May 23. https://www.reuters.com/article/us-sqm-results/chile-lithium-producer-sqm-delays-atacama-expansion-amid-price-slump-idUSKCN1ST2DX.

Sherwood, Dave. 2019. *Chile, Once the World's Lithium Leader, Loses Ground to Rivals.* May 30. https://www.reuters.com/article/us-chile-lithium-analysis/chile-once-the-worlds-lithium-leader-loses-ground-to-rivals-idUSKCN1T00DM.

Sherwood, Dave. 2019. *How Lithium-rich Chile Botched a Plan to Attract Battery Makers.* July 17. https://www.reuters.com/article/us-chile-lithium-focus-idUSKCN1UC0C8.

Sherwood, Dave. 2019. *Molymet Drops Plans for Battery Parts Factory in Chile.* July 13. https://www.reuters.com/article/chile-lithium/molymet-drops-plans-for-battery-parts-factory-in-chile-idUSL2N24E04T.

Sherwood, Dave, and Jane Chung. 2019. *South Korea's POSCO Drops Plans for Chilean Battery Material Plant.* June 21. https://www.reuters.com/article/chile-lithium-posco/south-koreas-posco-drops-plans-for-chilean-battery-material-plant-idUSL2N23Q1EB.

SQM. n.d. *Lithium Hydroxide.* Accessed August 9, 2019. https://www.sqm.com/en/producto/hidroxido-de-litio/.

Sturgeon, Timothy J, Olga Memedović, Johannes Van Biesebroeck, and Gary Gereffi. 2009. "Globalization of the Automotive Industry: Main Features and Trends." *International Journal Technological Learning, Innovation and Development* 7-24. https://doi.org/10.1504/IJTLID.2009.021954.

Sumitomo Coporation in Europe. 2017. *Stable Supply of a Key Material of Power Sources for Advanced Equipment.* February. https://www.sumitomocorp.com/en/europe/business/case/group/29747.

Talison Lithium. n.d. *About.* Accessed July 23, 2019. https://www.talisonlithium.com/about.

Talison Lithium. n.d. *Greenbushes Project.* Accessed July 23, 2019. https://www.talisonlithium.com/greenbushes-project.

Talison Lithium. n.d. *Lithium.* Accessed August 9, 2019. https://www.talisonlithium.com/lithium.

The Economist. 2018. *What if China corners the cobalt market?* March 14. https://www.economist.com/finance-and-economics/2018/03/24/what-if-china-corners-the-cobalt-market.

The State Council of the People's Republic of China. 2017. *China to Invest Big in 'Made in China 2025' Strategy.* October 12, accessed 2017. http://english.gov.cn/state_council/ministries/2017/10/12/content_281475904600274.htm.

Thompson, Brad. 2019. *Tianqi Puts Brakes on Landmark WA Lithium Plant Expansion.* September 10. https://www.afr.com/companies/mining/tianqi-puts-brakes-on-landmark-wa-lithium-plant-expansion-20190910-p52ppp.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2002. *Commercial Development of Regional Ports as Logistics Centres.* Report, New York: United Nations. https://www.unescap.org/sites/default/files/pub_2194_fulltext.pdf.

University of Birmingham. 2018. *New High-Capacity Sodium-Ion Could Replace Lithium in Rechargable Batteries.* September 12. https://phys.org/news/2018-09-high-capacity-sodium-ion-lithium-rechargeable-batteries.html.

University of Wollongong. 2018. *Sodium-ion battery packs a punch.* April 5. https://phys.org/news/2018-04-sodium-ion-battery.html.

Volkswagen Group. 2019. *Volkswagen Group Secures Lithium Supplies.* April 5. https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-group-secures-lithium-supplies-4804.

Wanli, Yang. 2019. *'World-class' Deposit of Lithium Found, Could Ease Reliance on Imports.* June 5. http://www.chinadaily.com.cn/a/201906/05/WS5cf71576a31051914270113a.html.

Wietlisbach, Samantha, and Adam Gao. 2018. *Chemical Economics Handbook: Lithium, Lithium Minerals, and Lithium Chemicals.* IHS Market.

Willis, Ray, Howard Buckley, and Neil Prentice. 2018. *Australia's Opportunity in the Lithium Battery Boom.* January 30. http://futuresmart.com.au/news/2018/lithium-industry-in-australia.

Appendix A
Tables

Measures by Key Material

Table A.1 Unprocessed (HS 2530.90) lithium trade measures, percent of value, 2018

Country	Coverage ratio: Unprocessed imports to unprocessed exports	Unprocessed exports to all lithium exports	Unprocessed imports to all lithium imports	Trade in unprocessed to all lithium trade	Unprocessed exports to all goods exports	Unprocessed imports to all goods imports	Trade in Unprocessed to All Goods Trade
Argentina	49,980.1	0.0	44.5	9.5	0.0	0.0	0.0
Australia	1.1	99.6	62.4	99.0	0.5	0.0	0.2
Chile	280.7	0.1	45.8	0.3	0.0	0.0	0.0
China	1,015.7	12.4	77.5	52.7	0.0	0.1	0.0
Japan	827.4	22.6	11.3	12.0	0.0	0.0	0.0
Korea, Republic of	487.0	27.4	9.1	10.3	0.0	0.0	0.0
United States	62.2	32.1	25.2	29.0	0.0	0.0	0.0

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; USITC staff calculations.

Table A.2 Processed (HS 2836.91 and 2825.20) lithium trade measures, percent of value, 2018

Country	Coverage ratio: Processed imports to processed exports	Processed exports to all lithium exports	Processed imports to all lithium imports	Trade in processed to all lithium trade	Processed exports to all goods exports	Processed imports to all goods imports	Trade in processed to all goods trade
Argentina	2.7	87.6	0.0	70.8	0.1	0.0	0.0
Australia	3,343.8	0.0	0.0	0.3	0.0	0.0	0.0
Chile	0.0	88.6	0.0	88.3	1.2	0.0	0.7
China	219.2	14.1	0.0	17.2	0.0	0.0	0.0
Japan	37,773.6	1.9	0.0	40.6	0.0	0.0	0.0
Korea, Republic of	2,418.0	34.2	0.1	55.3	0.0	0.1	0.0
United States	550.2	5.7	0.0	20.8	0.0	0.0	0.0

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; USITC staff calculations.

Table A.3 Refined lithium (HS 2826.90 and 2805.19) trade measures, percent of value, 2018

Country	Coverage ratio: refined imports to refined exports	Refined exports to all lithium exports	Refined imports to all lithium imports	Trade in refined to all lithium trade	Refined exports to all goods exports	Refined imports to all goods imports	Trade in Refined to All Goods Trade
Argentina	102.4	12.4	46.8	19.7	0.0	0.0	0.0
Australia	111.4	0.4	23.2	0.8	0.0	0.0	0.0
Chile	1.8	11.3	50.5	11.5	0.2	0.0	0.1
China	7.8	73.5	3.5	30.1	0.0	0.0	0.0
Japan	997.9	75.5	45.7	47.4	0.0	0.0	0.0
Korea, Republic of	1,296.6	38.4	34.1	34.4	0.0	0.1	0.0
United States	44.9	62.1	35.1	50.2	0.0	0.0	0.0

Source: IHS Markit, Global Trade Atlas, accessed August 16, 2019; USITC staff calculations.