

Identifying Bottlenecks in the Supply Chains of Key Sectors

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The Open Markets Institute initially prepared the following report in response to a request by the Bureau of Industry and Security on April 6, 2022, on how to advance supply chain resiliency and security in the following sectors: semiconductors and material inputs; solar photovoltaics, critical minerals and materials; lithium-ion batteries; and pharmaceuticals. Research into these key sectors will inform the United States – European Union (EU) Trade and Technology Council Secure Supply Chains Working Group. This report by the Open Markets Institute will focus on efforts and policies that the Supply Chains Working Group of the U.S.-EU Trade and Technology Council can take to strengthen the resiliency of supply chains. *These efforts will include recommendations on how to increase visibility and transparency of supply and demand related to the above-mentioned sectors, identifying sectorial capabilities, and promoting policy measures and strategies to strengthen supply chain resilience, diversification, and security.*

I. Introduction

Over the past few decades, the international economic system has been characterized by increasingly dangerous geographic and corporate concentration of industrial capacity. This concentration has been made evident by numerous disruptions to key production systems in recent years. These include public health crises, natural disasters, and global conflicts, with the two most recent being the COVID-19 pandemic and the ongoing Russo-Ukrainian War.

Prior to these conflicts other events made evident the dangers posed by extreme concentration.¹ This includes a 7.6 magnitude earthquake in Taiwan in 1999. The earthquake stopped the production and distribution of semiconductors in the city of Hsinchu, which, in turn, resulted in widespread shutdowns of factories across the U.S. and Asia. Another major event was the Tohoku earthquake in March 2011 in Japan, which resulted in a major drop in industrial activity around the world,² with especially deep disruptions in the global automobile and aerospace sectors.³ The eruption of the volcano Eyjafallajokull in Iceland in 2010 and the SARS epidemic, among others, also resulted in breakdowns of vital industrial production.

Political and military crises also pose major threats to highly concentrated industrial systems, because of the ability of certain nations to cut off supplies of vital materials. In 1973, OPEC countries carried out an oil embargo on the U.S. for its support of Israel during the Yom Kippur War, causing an oil crisis in the U.S. In 2010, China cut off supplies of rare earth minerals to Japan, due to a dispute over control of the Senkaku Islands. There has even been renewed discussion of the possibility of military conflict between China and Taiwan.⁴ According to the Pentagon, "One of the biggest lessons learned during the COVID-19 pandemic is that the supply chain is vulnerable to offshore suppliers, particularly adversaries such as China."⁵

The most recent lessons we've learned about the threats posed by this concentration of capacity were taught by the COVID-19 pandemic. The pandemic triggered shortages of vital supplies of personal protective equipment and pharmaceuticals, which were primarily manufactured in Asia, and the weakness in our capacity to manufacture these and many other essential items in a timely fashion. These disruptions spurred the Trump administration

to invoke the Defense Production Act to speed the production of these critical goods. This effort, in turn, demonstrated the difficulty of increasing production in a timely manner.^{6,7}

This concentration of capacity poses an enormous threat to the economic and national security of the U.S. and the EU, as well as key allies in Asia, such as Japan, South Korea, and Taiwan. In response, both the U.S. and the EU have begun to take steps to re-shore industrial capacity for critical goods. So far, in the U.S., the Biden administration has released a 100-day supply chain review report and on February 24, 2021, the administration released a capstone report providing an overview of progress made and recommendations on boosting supply chain resilience.⁸

While these efforts are steps in the right direction, the Open Markets Institute also believes that the concentration of control over central nodes in key production systems by monopolists abroad must be broken. The U.S. and EU should also take steps to break dangerous concentrations of capacity and control that exist within their own borders and to ensure a safe distribution of capacities among their allies.⁹

This report will examine who controls supply in global supply chains for the sectors listed above, and the strategies the U.S. and EU can take to target these areas in the global supply chain for the purpose of increasing resiliency in these critical materials, components, and products.

In addition, this report will distill key lessons from the wider supply chain disruptions the United States has experienced in recent years, and which have worsened and accelerated dramatically since the beginning of the COVID-19 pandemic in early 2020. These lessons will help us understand the source of this set of crises in flawed policy decisions a generation ago, and will help us identify overarching reforms that will help us address these problems today, in a timely, efficient, and effective manner.

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II. Increasing Visibility and Transparency of Supply and Demand & Mapping Existing Sectoral Capabilities

The Bureau of Industry and Security has requested information on increasing the visibility and transparency of supply chains. The Open Markets Institute believes that increasing the visibility of chokepoints and bottlenecks in the global supply chain of critical goods is an essential step in identifying sectoral vulnerabilities for many industries such as critical minerals, solar panels, semiconductors, batteries, and pharmaceuticals. This will inform the U.S. and EU on areas where cooperation is necessary to increase supply chain resiliency.

CRITICAL MINERALS AND MATERIALS

A key feedstock of semiconductor and photovoltaic (PV) technology is polysilicon. It is a high purity form of the globally abundant mineral silicon which is extracted from quartzite. This mineral's use has increased in the last few decades as demand for both semiconductors and solar panels has soared.

The semiconductor industry makes up 10% of polysilicon applications.¹⁰ Polysilicon is formed into large ingots in the semiconductor production process then sliced into wafers. Polysilicon is also used in further processing as specific parts of the wafer are filled with the material.¹¹

China dominates the production of polysilicon with a 76% global market share in 2021.¹² This share is up from 30% in 2012.¹³ This number is even greater for polysilicon in the solar sector, exceeding 80% and on track to reach 100%.¹⁴ The largest producers in the U.S. are Corning, Hemlock, and REC Silicon. Hemlock Semiconductor is the major producer of polysilicon in the U.S. and is owned by U.S.-based Corning and Japan-based Shin-Etsu Chemical. It was acquired in 2016 by a joint venture of Dow Chemical Co. and Corning, called Dow Corning. Dupont sold its 40% stake in the company to Shin-Etsu in 2020.¹⁵

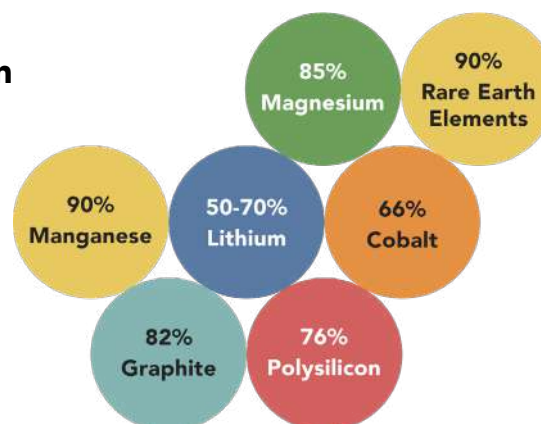
In recent years, tariffs imposed by China have severely damaged Hemlock's semiconductor business and the wider polysilicon sector in the U.S. Further, China's actions resulted in the loss of 1,400 jobs¹⁶ in the United States and a drop in exports from \$1 billion in 2011 to \$107 million in 2018.¹⁷ The tariffs also destroyed industrial capacity in the United States. Since 2014 Hemlock has shuttered its plant in Tennessee, and REC Silicon has closed a plant in Washington state.¹⁸ REC is based in Norway but is owned by the South Korean conglomerate Hanwha Corp.

The 10 largest polysilicon manufacturers in 2021 were primarily located in China, while German producer Wacker took the fourth spot, and Hemlock took the ninth.¹⁹ China's pricing power in the market is unmatched. In October 2021, the price of silicon metal shot up 300% in a mere two months.²⁰ This price increase was caused by production cuts in China because of power shortages.²¹

Although quartzite is abundant, the U.S. produces nearly all the high purity quartz needed for solar panels. The entire global supply of HPQ is mined from Spruce Pine, North Carolina, which means that much of the world's integrated circuit and solar PV applications are dependent on mining activities in the region.²² Three of the largest companies operating in Spruce Pine are US Gypsum Corp., a subsidiary of Germany-based Knauf, Belgium-based Sibelco, and the Quartz Corp., which is a 50/50 joint venture of Norway-based Norsk Minerals and France-based Imerys Minerals.²³ Unimin and Quartz Corp. produce about 80-90% of the HPQ mined.²⁴ While HPQ production is dominated by the U.S., there are other ways to produce the quartz but these methods are more time consuming and less economical. In June 2021, the Biden administration placed export controls on Chinese companies producing solar panels because of human rights violations in Xinjiang.²⁵ However, it is unlikely that the U.S. applied these export controls on companies in the U.S. supplying HPQ because it is an input material. An export control would be effective in crippling the Chinese solar industry, as the largest HPQ producer in China is Jiangsu Pacific Quartz Co., which produces 20,000 tons of the material compared to Spruce Pine's 200,000 tons per year.²⁶

Currently the processing of many other critical minerals and metals is heavily concentrated in single nations with China especially dominant in metal processing. This concentration in China has made fragile the supply chain of many critical minerals and metals. China produces 82% of the world's graphite²⁷, 90% of manganese, 76% of polysilicon, 50-70% of lithium, 66% of cobalt, 85% of magnesium, and 90% of rare-earth elements (REE).²⁸ Russia produces 40% of the world's palladium.²⁹ These metals play major roles as inputs for clean energy technologies, semiconductors, and other industrial applications.

China's Global Share of Mineral Production



China's BTR Material Group accounts for 70% of the graphite production used in electric vehicles.³⁰ Factory closures in China because of power rationing led to a decrease in the global supply of graphite last winter, resulting in a major price increase for the mineral.³¹

Chinese producers control 90% of the production of manganese³², which plays a major role in important industrial applications ranging from electric vehicle manufacturing to clean energy technology. China has created a cartel of manganese producers known as the Manganese Innovation Alliance, which serves to allow control over global prices.³³ The 40 companies³⁴ in the alliance include Ningxia Tianyuan Manganese Industry Group, Hunan Southern Manganese, and Wuling Manganese.³⁵

Chinese producers also have successfully cornered the global REE market. China dominates refining and production with a 90% global market share. China's share of global mining is far less, however, with the country controlling only about 54% of global supply.³⁶ The difference is made up by rare earths produced in the U.S. and other nations and then shipped to China for refining. In December 2021, China approved a merger between China Minmetals Rare Earth, Chinalco Rare Earth & Metals, and China Southern Rare Earth Group, creating China Rare Earth Group, a state-owned enterprise now under the state assets regulator.³⁷ This merger is largely an attempt by China to gain dominance over the global pricing of rare earths. The new company, China Rare Earth Group, is now the second largest REE producer after China Northern Rare Earth Group.³⁸

China's dominant presence in the REE market is a major vulnerability for the U.S. and the EU as the Chinese government has used their monopoly as a geopolitical weapon in disputes in the past decade. In 2010, China blocked the export of rare earth metals to Japan after a dispute arose between the two countries.³⁹ In September 2010, a Japanese coast guard arrested a Chinese fishing boat captain near the Senkaku/Diaoyu Islands in the East China Sea after the Chinese boat rammed two Japan Coast Guard vessels. REE exports resumed after the dispute was resolved but prompted concern from Western nations that China would be willing to use its rare earth monopoly for geopolitical purposes.⁴⁰

SEMICONDUCTORS AND SEMICONDUCTOR MATERIAL INPUTS

TSMC, located in Taiwan, manufactures most of the logic chips needed for computers and electronics. It holds a 54% global market share in foundry capacity for the sector as a whole, and controls close to a complete monopoly of many specific types of semiconductors.⁴¹ TSMC has made clear that it intends to

protect this dominance, promising to invest more than \$100 billion over the next three years to upgrade manufacturing capacity and boost R&D, with \$28 billion going to capital expenditures that will fund the manufacture of advanced chip technologies needed for technologies like artificial intelligence and 5G.⁴² The corporation currently has a 90% global market share⁴³ in these advanced chips. American corporations such as Intel are racing to keep up with advancements in semiconductor manufacturing.⁴⁴

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But TSMC isn't Taiwan's only example of dominance in manufacturing semiconductors; Taiwan boasts an over 60% global market share in the manufacture of all semiconductors thanks to the efforts of other Taiwan-based corporations, such as United Micro Electronics (UMC) and Advanced Semiconductor Engineering Group (ASE).⁴⁵ ASE is also a major leader in the assembly, testing, and packaging market for semiconductors. Taiwan accounts for 54% of all assembly, test, and packaging (ATP) revenues⁴⁶ versus China's 12% (some estimates put this figure as high as 22%⁴⁷). The major companies involved in this sector also include Taiwan-based SPIL and Powertech, and China-based JCET Group, Tongfu Microelectronics, and Tianshui Huatian Technology.⁴⁸ While China still has a minority share compared to Taiwan for overall ATP, China was the biggest market for packaging materials at 25%.⁴⁹ ATP is a supply chain vulnerability for the U.S. which has only one company, Amkor Technologies, specializing in the sector.⁵⁰ Amkor has no facilities in the U.S. Its only factories are in various locations in Asia (China, Japan, South Korea, Malaysia, Philippines, and Taiwan) and one in Portugal.⁵¹



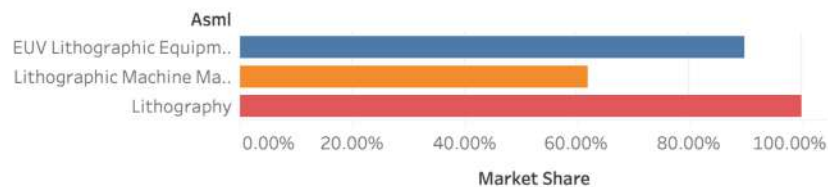
Even more alarming is that 63% of total manufacturing capacity for these logic chips is located in East Asia, with the figure rising to close to 100% for the most advanced chips.⁵² This hyper-concentration of manufacturing capacity poses a grave threat to supply chain resiliency for different sectors of the global economy.

But it isn't just logic chips that are highly concentrated in East Asia.⁵³ So too are most memory chips used to store data, with an estimated 90% of manufacturing capacity concentrated in East Asia. Some 72.7% of the global dynamic random-access memory market, for instance, is held by two South Korean companies, Samsung and SK Hynix, with 43.5% and 29.2% respectively.⁵⁴

Discrete semiconductors, used in devices designed to generate or sense light, are also highly concentrated. About 68% of manufacturing for these devices is concentrated in East Asia.⁵⁵ In more advanced chip technology, TSMC also dominates production, with over 80% global market share for 10nm to 5nm chips, which represent a \$21.1 billion market.⁵⁶

The lithography process of semiconductor manufacturing is also highly concentrated. Indeed, the process is monopolized by one company, ASML of the Netherlands.⁵⁷ Photolithographic machines use light to bring together integrated circuits and silicon wafers and will be a major necessity as more circuits are integrated onto wafers, to produce advanced chips. ASML has a 62% global market share in the manufacturing of lithographic machines,⁵⁸ but a 90% global market share in the lithographic business overall, and a 100% global market share in EUV lithographic equipment.⁵⁹

ASML Market Share



The fabless semiconductor design business relies primarily on design software tools offered by just four corporations. Three (Cadence, Synopsys, and Ansys) are American, while Siemens EDA is German. The four companies have a 90% global market share in electronic design automation software.⁶⁰

Another example of high concentration in production is in the manufacture of wafers for integrated circuits. In this instance, however, the problem is mainly domestic in nature, and hence easier to address. The U.S.-based corporation Wolfspeed has a 62% global market share in the production of silicon carbide (SiC) wafers, which are used primarily for small and more efficient electronics devices and considered to be the material of the future.⁶¹ Wolfspeed manufactures at two facilities in North Carolina and at a factory in Fayetteville, Arkansas.⁶² The corporation has also broken ground on a production facility in New York.⁶³ In addition, an array of other players in this market include II-VI and Dow Corning; Wolfspeed's concentration of production may pose supply risks down the line.⁶⁴ But the current market for SiC wafers does not yet appear to be large enough to pose structural threats, accounting for only 7.5% of total wafers in 2016.⁶⁵

The general market for silicon wafers is more diverse in corporate market share than SiC chips. The industry is dominated by five major players which together

hold a 100% global market share.⁶⁶ The largest are Japanese companies Shin-Etsu (32% market share) and Sumco (25% market share).^{67 68} Both players have production facilities solely in Japan which means over half of the world's production of silicon wafers is concentrated in the country, representing a major supply chain risk.

Another major bottleneck in the semiconductor supply chain is substrates, which make up more than 30% of the costs for IC packaging, and where concentration in the industry continues to contribute to reduced supply chain resiliency.⁶⁹ Ajinomoto Build Up Film (ABF) substrate business is a major part of chip packaging and is at the heart of package manufacturing for CPUs, GPUs, and other chipsets. The industry is dominated by a few players including Ajinomoto, Nan Ya, Kinsus, Ibiden, and Unimicron, and shortages over the past year have been a result of low production capacity.⁷⁰ Nan Ya has seen a 1,219% rise in its stock in the past three years as a result of surging demand and revenue for substrates,⁷¹ and some analysts have lamented the firm's pricing power, arguing that it could raise prices by 35% during the year.⁷²

Another major substrate is bismaleimide triazine (BT) resin. The substrate is used in logic chips, mobile phone MEMs chips, communication chips, and memory chips. Mitsubishi Gas Co. first developed BT resin in 1978⁷³ and is still the leading provider.⁷⁴ In 2011, a tsunami in Japan caused damage to the company's chemical plants, leading to a global shortage of BT resin as 90% of the substrate was produced in northeastern Japan.⁷⁵ The company has lost global market share but still produces 40% of the world's BT resin.⁷⁶

Another important substrate is direct bonded copper (DBC) which is used for high powered semiconductor modules.⁷⁷ The largest global producers are Rogers, KCC, and Ferrotec (Shanghai Shenhe).⁷⁸ There are only three other domestic producers in the U.S.⁷⁹ which include Valley Design Corp., Stellar Industries Corp. and Remtec.⁸⁰ Rogers and KCC together account for over 70% of global market share in production.^{81 82} Rogers has a globally distributed manufacturing base.⁸³ In November 2021, DuPont acquired Rogers for \$5.2 billion.⁸⁴

Electronic specialty gases are a key input in the semiconductor production process, and integrated circuits accounted for 42% of the gas applications.⁸⁵ Hundreds of gases are used, and the industry is heavily concentrated. Four companies make up 81% of the market, with the top two being Linde with a 32% global market share and Air Liquide with a 31% global market share.⁸⁶ Concentration levels for the capacity to manufacture specific gases are often much higher, up to almost 100%. For example, Ukraine supplies more than 90% of U.S. semiconductor-grade neon.⁸⁷ Over the past decade Linde has

participated in numerous mergers and divestitures, with the most prominent being the merger between Linde and American industrial gas company Praxair.⁸⁸ In 2018 Linde agreed to sell its North American operations to German company Messers and its private equity firm CVC Capital Partners.⁸⁹

Many foreign companies rely on Western gas producers for semiconductors. 62% of China's electric gas production is used for semiconductors, and the top five firms in the country, which include Praxair, Linde, Taiyo Nippon Sanso, and Air Liquide, have an 85% global market share.⁹⁰ China's top four gas makers only account for 6.27% of China's gas supply.⁹¹

In addition to concentration in the industrial gas sector, concentration of perfluoroalkyl and polyfluoroalkyl substances (PFAS), which are used for cooling the etching process, is also a major supply chain risk. In April 2022, shutdowns at a 3M plant in Zwijndrecht, Belgium resulted in PFAS shortages. 3M has a 90% global market share in the supply of coolants for the semiconductor industry, and 80% comes from the plant in Zwijndrecht.⁹² The other 10% is sourced from one plant in Italy, operated by the company Solvay.⁹³

While silicon-based power electronics still dominate the market, a new faster and more energy-efficient class of microchips has become increasingly popular over the past few years. The market for these chips, also known as wide-bandgap (WBG) semiconductors, has grown from \$200 million in 2015 to \$600 million in 2020.⁹⁴ And the rate of growth is increasing fast, as these chips are put to use in electric vehicles, renewable energy applications, and electrified industrial technologies.

Two types of chips exist in this market for WBG semiconductors which include silicon carbide (SiC) chips and gallium nitride chips (GaN). While the U.S. has a strong position in the market for SiC wafers, Taiwan controls more than 50% of the production of GaN wafers.⁹⁵ Companies such as TSMC, EPISIL, and Unikorn are the main Taiwanese companies involved in production. The U.S. has a single facility able to produce GaN chips.⁹⁶ Meanwhile, only one U.S. company – Wolfspeed – has the ability to produce the wafers needed for these chips.

The production of SiGe chips (silicon germanium) is also primarily concentrated with one company, Tower Semiconductor, which controls more than 60% of the market.⁹⁷ In February 2022, Intel announced that it would acquire Tower for \$6 billion.⁹⁸ SiGe chips are a class of semiconductors that improve power consumption, reception distance, and the dynamic range of receiver devices. These chips are used increasingly in cellular and wireless communication devices and other devices used for radio frequency applications.⁹⁹

In regard to radio frequency chips, French company Soitec has a 70% global market share in the production of silicon-on-insulator chips, which are essential to building radio frequency chips.¹⁰⁰ Soitec has three manufacturing facilities with two in Bernin, France, and the other in Singapore.¹⁰¹

Gallium is a major mineral input needed to produce GaN chips, and China produces more than 90% of global gallium with some estimates noting production is higher than 95%.¹⁰² The Department of Energy's Semiconductor Supply Chain Deep Dive Assessment notes that gallium has "the riskiest supply chain of all critical minerals."¹⁰³ Neither the U.S. nor Europe can produce gallium metal and must rely on recycling.¹⁰⁴ Currently in the U.S., only one company recovers and refines high purity gallium from imported gallium metal and scrap.¹⁰⁵

Another key vulnerability for the U.S. and Europe are photoresists. These chemicals are placed on a wafer and used to form a circuit pattern. Photoresists are essential to the etching process of semiconductors and help create permanent circuit patterns for chips. Japan has a monopoly in the market with a 90% global market share.¹⁰⁶

Concentration is also high in the market for chemical mechanical planarization materials. These materials are essential to the lithography process. Materials such as chemical slurries and polishing pads are used to prepare microchips for lithography by making layers flat. Dupont and Cabot Electronics have a 56% share of the CMP slurry global market.¹⁰⁷ Dupont has a 78% global market share in CMP pads. In December 2021, Intel warned of dangers posed by this concentration, noting that the International Trade Commission's plans to ban imports of CMP materials from Taiwan and Japan could worsen the semiconductor shortage.¹⁰⁸ Dupont produces its CMP materials in Taiwan and Japan and was accused of infringing on patents held by CMC Materials. Later that month, the ITC ruled against DuPont and banned the import of CMP materials made by the company in Taiwan and Japan.^{109 110}

Another major process needed for semiconductor production is sputtering, which strips the atoms of argon ions and places them on a thin film on chip wafers. Japanese company JX Nippon has a 55% global market share in this process.¹¹¹ All of JX Nippon's production facilities are located in Japan,¹¹² although the company just announced plans in April 2022 to build a facility in Mesa, Arizona.¹¹³

Another chokepoint is in the crystal-growing furnace equipment needed to make wafers for semiconductors. Only one company, Germany-based

PVA TePLA Group, supplies customers in the silicon and silicon carbide semiconductor market. PVA TePLA group manufactures most items at sites Germany but also has two facilities in the U.S. and one in Italy.¹¹⁴

The market for electron beam mask writers is also concentrated. The technology is used to create patterns on silicon wafers. NuFlare, a subsidiary of Toshiba, has a 50% global market share for electron beam mask writers.¹¹⁵ NuFlare has one listed location in Yokohama, Japan.¹¹⁶

The bevel etcher market is also highly concentrated; the market is a duopoly. Bevel etchers are used to remove metal and non-metal films from the edge of a semiconductor (also known as a bevel). U.S.-based Lam Research had a monopoly on this technology until the emergence of South Korean fab company PSK.¹¹⁷ PSK now has a 30% global market share.¹¹⁸

The market for mask writers is concentrated. Mask writers are used to create patterns on semiconductor substrates such as wafers. This is needed for the creation of high-end electronics and high-end displays. Swedish company Mycronic is the sole source supplier for laser mask writers.¹¹⁹

Ion implantation devices are also concentrated. The process of ion implantation is needed in semiconductor device fabrication and involves the modification of a material surface through the placement of ions onto a solid material. This changes the physical surface and chemical properties of a material. U.S. based Axcellis technologies holds a 67% market share¹²⁰ in the high energy ion implanter market and has manufacturing locations only in Beverly, Massachusetts and at one newly opened facility in South Korea.¹²¹

Semiconductor Material Chokepoints
Build Up Film Substrates
Bismaleimide Triazine (BT Resin)
Direct Bonded Copper
Industrial Gases
Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)
Chemical Slurries
Sputtering
Crystal Growing Furnaces
Mask Writers
Ion Implantation Devices
Bevel Etchers
Photoresists

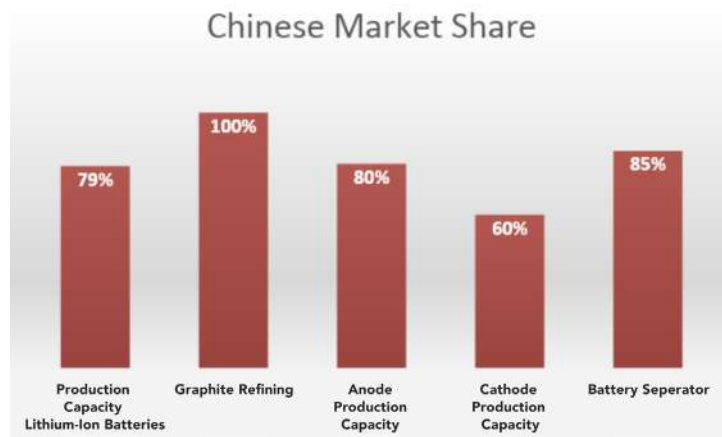
LITHIUM-ION BATTERIES

China dominates the manufacturing of electric vehicle batteries with Japan and South Korea in second and third place. China has 79% of global capacity for lithium-ion batteries.¹²² Many of the Chinese-based plants are actually owned by foreign manufacturers, including South Korea's LG Chem and Japan's Panasonic.

The EV battery supply chain is characterized by three main stages which include cell, module, and pack production.¹²³ The module and pack assembly stage of production tends to happen near vehicle assembly plants as a result of the high costs and safety regulations associated with their shipment. But cell manufacturing and the chemical refining needed for that stage is heavily concentrated in East Asia with China dominating production. Much of the materials needed to assemble batteries in the United States, still comes from one country, China.

The cell manufacturing stage of battery production involves the use of two electrodes: a cathode and anode. The anode is made from graphite, and China has a 100% global market share in the refining process for the EV battery supply chain.¹²⁴ China's BTR New Material Group accounted for 70% of graphite production in the EV battery supply chain. Cathodes are made up of a mix of minerals such as lithium, nickel, and cobalt. China produces 80% of all anodes, and over 60% of cathodes,¹²⁵ with the rest of manufacturing occurring in South Korea and Japan. The minerals needed for cathodes are refined primarily by China as well with a 65% global market share in nickel refining, 82% for cobalt, 59% for lithium, and 93% for manganese.¹²⁶

These electrodes must be kept apart by a thin plastic film device known as a separator, and within these separators are liquid electrolytes composed of dissolved lithium salts. While the U.S. is home to companies that manufacture separators, the market for electrolytes is heavily concentrated and has been monopolized by suppliers in East Asia. In 2015 China's top 10 companies accounted for over 85% of production.¹²⁷



The United States and the European Union generally lack capacity to manufacturing electric vehicle battery cells. Four of the 10 largest manufacturers are based in China, and China is on track to build 148 battery mega-factories by 2030, compared to 11 in North America and 21 in Europe.¹²⁸ China currently accounts for 558 GWh of li-ion manufacturing capacity or 79% of the world's total.¹²⁹ The U.S. has 44 GWh of capacity, and 6.2% and European countries make up 68 GWh or 10%.¹³⁰

The EU's largest producers are Hungary and Poland which together make up 50 GWh of capacity, or 7.1%.¹³¹ These factories are located in Wroclaw, Poland (run by LG Solution Wroclaw), and in Budapest (run by Samsung). The Wroclaw facility is the largest manufacturer of batteries for the automotive industry.¹³²

Finland plans to build one of the world's largest refineries for cobalt and nickel sulfate. The country already refines half of Europe's cobalt and is a major hub for refining nickel. Russia's Nornickel has invested in nickel production in the country, and Umicore and the German company BASF also have invested.¹³³ Finland's major producer of battery packs is Valmet Automotive, which is owned partly by Chinese manufacturer CATL.

Chinese investment into EV batteries manufacturing in Europe has increased in recent years. Gotion High-Tech has partnered with Volkswagen to create battery cells, while Envision AESC has expanded manufacturing on the continent with the goal of supplying French carmaker Renault.¹³⁴ CATL has also signed deals to supply companies such as BMW.¹³⁵

A major advantage of Chinese EV battery production is the ability of Chinese companies to vertically integrate their supply chain from raw material extraction to manufacturing. More Western EV manufacturers seek to emulate this approach, with Tesla even taking major stakes in mining companies. However, the prevalence of exclusive supply and battery development agreements to capture secure slices of the entire supply chain may be harmful to competition in the long run.

The prevalence of exclusive supply and battery development agreements to capture secure slices of the entire supply chain may be harmful to competition in the long run.

Sweden's Northvolt is Europe's leading battery manufacturer.¹³⁶ In December 2021, Northvolt completed the first European-owned gigawatt hour scale cell plant, in Skellefteå in northern Sweden, and introduced its first lithium-ion battery cell.^{137 138}

Europe faces significant bottlenecks in raw material supply for the production of battery cells. Deficits in nickel, cobalt, lithium, copper, and graphite are expected to continue for the next two years, and demand for all minerals is

expected to rise significantly by 2030.¹³⁹ Herbert Diess, CEO of Volkswagen has stated, “The supply chain for EVs will be the bottleneck, not only for us but also for all our competitors, because we need the capacities for the raw materials, for lithium, for nickel at the beginning, and still for cobalt. That has to be established.”¹⁴⁰

European production capacity for li-ion batteries is expected to increase by 1440% by the end of the decade.¹⁴¹ Much of Europe’s growth in the EV battery manufacturing market has come from significant amounts of Chinese and South Korean investment.¹⁴² CATL, Svolt Energy Technology, LG Chem, Samsung SDI, and SK Innovation all have announced plans to significantly increase capacity in Europe.

Noting this significant expansion, European leaders have created the European Battery Innovation Project. Twelve member states are investing \$3.5 billion in funding for innovation and research projects for the entire EV battery supply chain, from extraction to manufacturing and recycling.¹⁴³ The project will include 42 small- and medium-sized enterprises and startups from the 12 member states.¹⁴⁴ The project is expected to be completed by 2028.

European battery makers also have begun to sign agreements with Chinese mineral suppliers to ensure an adequate supply of minerals for batteries.¹⁴⁵ Volkswagen has signed supplier deals with Tsingshan Holding Group and Zhejiang Huayou Cobalt Co. While Tesla is the largest EV company in the U.S. and assembles li-ion batteries at facilities in Nevada, this assembly process does not involve the manufacturing of li-ion battery cells. The company sources its batteries from Asian manufacturers such as Panasonic, LG Energy Solutions, and CATL.¹⁴⁶

Lithium ion-battery manufacturing may experience slowdown in the future as global supply shortages of important chemical components are expected. Supplies of polyvinylidene fluoride, which is used to connect electrodes in battery cells, are expected to be in shortfall.¹⁴⁷ The four major players (Arkema, Solvay, 3F, and Dongyue) hold a 65% global market share.¹⁴⁸

PHARMACEUTICALS

The global supply chain of the pharmaceutical industry over the past few decades has been shaped by increasing corporate consolidation, offshoring to Asia, and the consolidation of manufacturing sites.¹⁴⁹

The global supply chain of the pharmaceutical industry over the past few decades has been shaped by increasing corporate consolidation, offshoring to Asia, and the consolidation of manufacturing sites.

China and India produce 80% of the active pharmaceutical ingredients (APIs) used to make generics sold in the United States. India is a major manufacturer of pills, and between 40% and 50% of generics consumed in the United States are imported from India.¹⁵⁰ India in turn imports some 70% of the APIs needed to make these generics from China.¹⁵¹ India has taken steps to reduce dependence on China in recent years. In 2020, the government creating a program that would reduce Chinese dependence by up to 35% before 2030 through increasing manufacturing capacity with a \$2 billion investment.¹⁵² However, Indian drugmakers have expressed strong concern over the production scheme as the government has made it a priority to create monopolies in the production of key drugs. For over 20 drugs, the government has granted approval for manufacturing to just one firm.¹⁵³

America's reliance on other countries for generic drugs has contributed to a shortage of more than 200 medications during the coronavirus outbreak in 2020, according to a report by the Department of Homeland Security.¹⁵⁴

About 37% of APIs supplying the European market come from India and 24% come from China.¹⁵⁵ For the U.S., 40% come from India and China. Just 21.7% of API sites that supply the U.S. are based domestically.¹⁵⁶ These numbers are tied to registrations filed with the Food and Drug Administration (FDA). However, much of this data has been subject to scrutiny, as sources have put the number of API facility dependence from China and India as much higher for both Europe and the U.S. Some sources report that as much as 80% of APIs used by both the U.S. and Europe come from China and India.¹⁵⁷

The production of APIs in China is concentrated with 50% coming from coastal provinces such as Zhejiang, Jiangsu, Hubei, and Shandong.¹⁵⁸ Much of these production sites can be considered sole source suppliers of APIs needed for key medicines. Additionally, quality issues at production sites accounted for 62% of shortages from 2013 to 2017.¹⁵⁹

U.S. drug access is increasingly subject to supply chain risks: An FDA analysis found that 97% of the most 47 prescribed antivirals had no U.S. source of API, and 92% of the top 111 used antibiotics also had no source of U.S. APIs.¹⁶⁰ According to the essential medicine lists created by the FDA, 72% of the most 94 used APIs had no U.S. production source.¹⁶¹

Some 80% of global PAP supplies, which is used to make acetaminophen, come from China. Additionally, three World Health Organization designated essential medicines, which are capreomycin, streptomycin, and sulfadiazine, have API suppliers solely based in China.¹⁶² There are certain lifesaving

antibiotics such as cephalosporins, azithromycin, and penicillin where 90% of APIs are based in China.¹⁶³

With regard to vaccines, India produces 65% of the world's DPT (diphtheria, pertussis, and tetanus) and tuberculosis vaccines.¹⁶⁴ India also produces 90% of the world's measles vaccines.¹⁶⁵ India has 70% of the world's hydroxychloroquine supply with Ipca Labs and Zydus Cadila being the two largest producers. Ipca accounts for more than 80% of that supply.¹⁶⁶

SOLAR PANELS

The global market for solar panel manufacturing and its essential components is heavily consolidated. There are two types of solar panels: crystalline silicon (c-Si) modules and cadmium telluride (CdTe) modules. The U.S. and European Union have little to no production capacity for c-Si solar panels.¹⁶⁷ The U.S. has high production capacity for CdTE modules. These modules represent 16% of the modules being developed for solar applications globally, compared to c-Si's 84%.¹⁶⁸ The CdTE supply chain doesn't rely on Chinese inputs as heavily as the c-Si modules, and the U.S. is a major manufacturer.¹⁶⁹ CdTE solar cells can be manufactured quickly and inexpensively and have a longer lifespan but tend to have lower efficiency levels. Only a single U.S. company creates CdTE modules and accounts for one-third of the U.S. market. CdTE solar panels meet 40% of the U.S. utility scale solar demand.¹⁷⁰ U.S.-based First Solar creates CdTE panels using cadmium telluride, though the company has recently begun seeing competitors.¹⁷¹ First Solar's three manufacturing locations are in Perrysburg, Ohio, Malaysia, and Vietnam.¹⁷²

The U.S. and European Union have little to no production capacity for c-Si solar panels. The U.S. has high production capacity for CdTE modules.

Cadmium (Cd) and Telluride (Te) are both byproducts of the refining and processing of other minerals. Cd is abundant, relatively easy to produce, and is primarily recovered as a byproduct of smelting zinc and lead ores. Te is a byproduct of copper refining. The U.S. imports most of the Cd it needs from China, South Korea, Japan, and Canada. China dominates in the production of cadmium with 10,000 metric tons of refinery production compared to the second largest producer, South Korea with 3,000 metric tons.¹⁷³ The U.S. imports tellurium from many countries, with Sweden being the major European partner and producer on the continent. The U.S. has 15% of global reserves of the mineral.¹⁷⁴

Three Chinese corporations (LONGi, Zhonghuan, and GCL) manufacture 71% of the world's solar modules. U.S. companies produce just 1% of solar modules, down from 22% about 20 years ago.¹⁷⁵ The U.S. also produces less than 5% of global polysilicon, down from 50% in 2007.¹⁷⁶ The wafers used for solar modules are also primarily manufactured by Chinese corporations which

have a 97% global market share.¹⁷⁷ Most of the world's modules are made by Chinese subsidiaries in three locations: Malaysia, Thailand, and Vietnam. Three-quarters of the solar cells used by the U.S. are made by Chinese corporations which then ship the products to Malaysia, Thailand, and Vietnam to be assembled into modules.¹⁷⁸

The top 10 players in the manufacture of PVs have 80% of the market.¹⁷⁹ The three largest are all Chinese: Longi Solar, Tongwei Solar, and JA Solar.¹⁸⁰

While highly reliant on c-Si PVs, the U.S. is a major producer and key exporter of materials needed for the production of PVs. The U.S. is a major exporter of Tedlar, which is a polyvinyl fluoride film used in 25-30% of PV modules.¹⁸¹ Dupont has a monopoly on the production of Tedlar, and the manufacturing sites are only in the U.S. Because of this concentration, the capacity utilization rate of the Tedlar is around 90%.¹⁸² A shortage occurred in 2005 because of high demand and inadequate supply.¹⁸³

The inverter market for PVs is heavily concentrated. Inverters are needed to convert DC energy to AC energy used by electric grids. A majority of inverter manufacturing occurs in Asia, and in particular China. Design for inverters is primarily dominated by large semiconductor companies based in the U.S., EU, Japan, and Asian countries.

U.S.-based Enphase and Israel-based Solaredge make up 95% of the global MLPE inverter market, which is used primarily for residential solar.¹⁸⁴ These two companies account for 88% of the U.S. market, with Enphase having a 48% share.¹⁸⁵ Pricing pressure has led competitors to exit the market, and both companies have obtained significant market share recently.¹⁸⁶

Other types of inverters used for commercial, or utility purposes tend to be dominated by companies based in Europe, China, and Japan. The U.S. relies more on European and Japanese companies for inverters for large scale solar applications. The world's 10 largest companies account for 76% of global trade, led by Chinese firms Huawei and Sungrow.¹⁸⁷ Together, these two companies account for 42% of the market.¹⁸⁸ Europe-based companies ABB and SMA previously manufactured inverters in the U.S., but in recent years those major U.S. facilities were closed and operations moved to Europe.^{189 190 191}

III. Strategies

Much of the supply chain fragility seen by the U.S. and EU in the past few years largely derives from anticompetitive mergers between large corporations and the financialization of these same corporations, culminating in the reduction and offshoring of industrial capacity.

The Open Markets Institute believes much of the supply chain fragility seen by the U.S. and EU in the past few years largely derives from anticompetitive mergers between large corporations and the financialization of these same corporations, culminating in the reduction and offshoring of industrial capacity. In January 2021, the Pentagon’s Office of Industrial Policy published an annual report on industrial policy and critical technologies that noted the dangers of the shareholder activist philosophy and the threat the financial industry poses to sectors critical to our national security.¹⁹²

This is evident in the semiconductor industry, as there is a long-term pattern of U.S. corporations taking steps to shut down existing semiconductor plants and offshore capacity to monopolists such as Asian chipmakers like TSMC or UMIC.¹⁹³

The liberalization of trade in the 1990s made it easier for financiers to move production facilities abroad and to freely trade across countries. Financiers motivated by increasing profits at any cost encouraged the outsourcing of manufacturing and looked to cut costs by relying on single and sole source suppliers. As economics scholar Nicholas Balas notes, “The spatial dynamics that have affected the semiconductor industry the last 15 years, such as outsourcing, the fables model, and offshoring, have been largely driven by the financial sector.”¹⁹⁴

Consolidation and financialization have also adversely impacted the pharmaceutical industry in the U.S. and Europe.

In 1984, generic drugs made up 19% of prescriptions in the United States,¹⁹⁵ but by 2019 they accounted for 90%.¹⁹⁶ The passage of the Hatch-Waxman Act in 1984 led to this rise in the use of generic drugs by streamlining the regulatory approval process. While the Hatch Waxman Act resulted in increased competition and lower prices for drugs – at least initially – financialized drug corporations looking to increase profit in the face of stiffer competition moved production overseas to Asia; drug corporations were incentivized to move production to take advantage of lower operating costs, cheaper labor, and government support.

The result has been the shuttering of domestic manufacturing capabilities in the United States. Large drug corporations like Pfizer, GalxoSmithKline, Novartis, and others slowly moved drug production overseas during the past 30 years.¹⁹⁷ This shift had such an impact that the last major facility that produced APIs in the U.S. was built 30 years ago.¹⁹⁸

The concentration of drug production in China and India and the lack of domestic production has made the U.S. susceptible to supply shocks. During the beginning of the global coronavirus outbreak, China closed numerous drug manufacturing facilities. As a result, India imposed strict restrictions on the export of 26 drugs and drug ingredients.¹⁹⁹ Although China was able to reopen its facilities and many drug producers had an inventory of drug ingredients to last up to two months, the implications of a major bottleneck or slowdown of drug production are striking.

Within the scope of the powers and recommendations of the U.S.-EU TTC Secure Supply Chains Working Group, together the U.S. and EU can break up dependence on monopolies abroad using various geoeconomic tools available to the International Trade Commission and the Department of Commerce and its subagencies.

The U.S. and the EU immediately should move to:

1) Break China's chokeholds on assembly work in electronics, on solar cell manufacturing, on lithium-ion battery manufacturing, and on refining of critical minerals. There are a strong array of trade tools, agreements, and export controls that the U.S. and the EU can use to accomplish this goal. There is strong precedent for these actions by past U.S. administrations.

In the late 1980s, the U.S. fended off a major assault by Japanese electronics corporations. During this time, Japan's government assisted in the development of their semiconductor industry,²⁰⁰ resulting in claims by U.S. companies of anti-competitive practices by the Japanese. Japanese firms increased their global market share of semiconductors from 15% in the late 1970s to 46% by 1986.²⁰¹ The cheap chips bankrupted U.S. manufacturer Mostek, which had been the largest producer of 16K RAM globally, and by mid-decade only Micron Technology and Texas Instruments remained in the business.

By 1986, the U.S. government had charged Japan with dumping semiconductors on the U.S. market and had enacted Section 301 tariffs. The government also began to encourage U.S. manufacturers to turn to other U.S. suppliers or to manufacturers in South Korea or Taiwan. These actions led the

U.S. and Japan to eventually settle their dispute by signing a five-year bilateral agreement in 1986 to increase market access in Japan.

This trend of dumping by foreign monopolists continues to this day. Chinese dumping of rare earths and solar panels have caused domestic producers, over the past few decades, to go out of business.

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Prior to the late 1990s, the U.S. was a major producer of REE. In the 1980s, 70% of the world's rare earths came from Mountain Pass Mine in California, run by Molycorp.²⁰² By the late 1980s the U.S. began to face fierce competition from Japanese producers who eventually controlled 52% of the market for magnet production, the chief use of REE. During this same time, the Chinese government began to develop their own rare earth processing industry and started a price war that drove down the global prices of REE. The Chinese also nationalized and cartelized the industry, and Molycorp was unable to compete with Chinese producers offering low prices.²⁰³

Solar panels are another example of a critical industry damaged by price wars waged by foreign monopolists. In 2011, American solar panel manufacturers filed a trade case with the DOC claiming that the Chinese solar industry was dumping solar panels on the U.S. market.²⁰⁴ This competition helped lead to the bankruptcies of major American solar companies.

In 1981, to save a U.S. automobile industry that was suffering from intense competition from Japanese competitors, Reagan's Trade Representative William Brock negotiated an agreement by which Japanese automobile competitors would reduce their share in the U.S. market and restrict exports of their products into the U.S.²⁰⁵ The policy, also known as voluntary export restraint, worked and the auto industry rebounded. Under current World Trade Organization rules, governments are forbidden from negotiating VERs. Any step taken using this trade tool would likely need to be reconciled with existing WTO frameworks.

More recently, the Trump administration's trade actions to break the global corporate concentration of communications equipment involved actions taken against Chinese communications corporations Huawei and ZTE.²⁰⁶ Such tariffs against Huawei and ZTE imports and export controls to China influenced contract manufacturers to move some production out of China. Companies such as Pegatron have begun to invest in production in Indonesia, Compal is planning to move to Vietnam, and Wistron has begun investing in India. Foxconn has begun to diversify production away from China.

2) More fully map the travels of key components to identify chokepoints globally. This includes identifying them in China and Taiwan, such as in packaging semiconductors. This should also include mandating that U.S. and European corporations audit and report their supply chain dependencies and areas of uncertainty. These audits and reports could be used for resilience stress tests in critical infrastructures.^{207 208}

3) Use the U.S. Defense Production Act and any analogous European authorities to increase both production and research of components in vulnerable industries laid out in this report and components in which the U.S. has a comparative advantage. The Biden administration has already taken these steps in the minerals and solar industry.

For example, the U.S. has a history in the production of metals and throughout the 20th century the U.S. government put in place industrial policy initiatives to both reduce dependency and bolster the production of key metals by coordinating production.

After World War II, the U.S. government established the Ames Laboratory and led the world in the field of rare earth separation and purification which helped lead to the development of permanent magnets. Ames transferred all their patents to the private sector in the '50s and '60s. One beneficiary was the U.S. corporation Molycorp which by the 1980s produced over 70% of global rare earth supplies from Mountain Pass Mine.²⁰⁹

Without U.S. government support, the rare earth's industry would not have taken off as it did in the '50s and '60s. After government support dwindled, private actors couldn't continue to prop up the industry. Rare earth production by private actors in the U.S. was not profitable when compared to low-cost Chinese production.

4) Coordinate in stockpiling critical minerals and components that are subject to supply constraints and export controls by other countries, particularly foreign adversaries.

After World War II, the U.S. passed the Critical Materials Stockpiling Act of 1946 which authorized over \$2 billion to be spent on the creation of a stockpile of metals and minerals that had been in short supply during the war. The Defense Production Act of 1950 later increased that amount. President Truman also created the Paley Commission which aimed to address mineral scarcity issues. By 1989 the value of the stockpile was \$9.6 billion.

Other policy options that the U.S. and EU should consider include:

5) Require all U.S. and European firms that purchase large numbers of semiconductors to multisource all essential components.²¹⁰ The government should incentivize or force firms to source components from numerous firms in the U.S. and in different locations across the globe, rather than relying on any single source supplier, even within its own borders. Such rules should aim to ensure that no one country fulfills 25% of total demand for any particular form of semiconductor.²¹¹ This would bolster greater competition in the industry and ensure that the supplies of major industries are not subject to the production shortfalls of one company or the shutdown of one country's entire economy as demonstrated by the COVID pandemic.

The semiconductor industry's history demonstrates how supply chains can be managed in this manner. Even while adopting Intel's technologies, IBM demanded that Intel license its technology to Advanced Micro Devices, in nearby Santa Clara, California. IBM did so, both to avoid production bottlenecks and to make sure Intel did not capture the ability to unilaterally raise prices. Additionally, the manufacturing of the COVID-19 vaccine illustrates the pitfalls of excessive geographic concentration of inputs and other components, as manufacturers complained about shortages and delays. Pushing for greater geographic and supplier diversity would address future shortfalls in production.²¹²

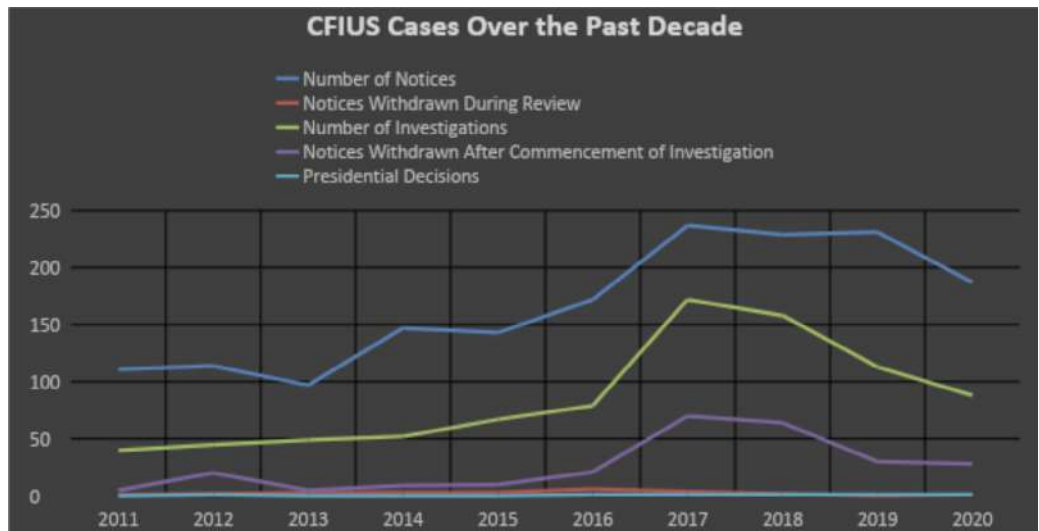
The government should incentivize or force firms to source components from numerous firms in the U.S. and in different locations across the globe, rather than relying on any single source supplier, even within its own borders.

6) Strengthen the Review Process for acquisitions by foreign companies of operations essential to U.S. and European efforts to ensure supply chain resilience.

At the present moment, this is especially important of acquisitions involving electric vehicle manufacturing. China's leading EV battery manufacturer CATL is looking to invest billions into acquiring EV battery companies globally.²¹³ Any of these acquisition targets with U.S. touchpoints should be on the radar of Committee on Foreign Investment in the United States (CFIUS) and European agencies.

There have even been instances of Chinese acquisitions involving the shift of EV battery manufacturing out of the U.S., specifically in the case of electrolytes. In 2012, German chemical manufacturer BASF acquired American electrolyte manufacturer Novolyte.²¹⁴ Six years later BASF sold its electrolyte business to Chinese industrial giant Capchem, and production since has been moving out of the U.S. ^{215 216} and shifting toward China.²¹⁷

CFIUS and an EU Investment Screening framework should set strict conditions and mandate strict public oversight for any approved mergers.²¹⁸ Some of these conditions could include prohibition of offshoring to countries with an already high amount of industrial capacity as well as prohibition of divestures from allied countries.



ADDITIONAL READING AND RESOURCES ON THESE ISSUES

- [Open Markets Primer on Supply Chains](#)
- [“Antimonopoly Power: The Global Fight Against Corporate Concentration,”](#) Barry Lynn, *Foreign Affairs*, July/August 2021. In this article we detail how the U.S. can fight the concentration of control over production and communications in the U.S.
- [“To Fix the Supply Chain Mess, Take on Wall Street,”](#) Garphil Julien, *Washington Monthly*, January/February/March 2022. This article details the decline of U.S. semiconductor manufacturing and how financiers have contributed enormously to the problem.”
- [Shock Proof: Building Resilient International Systems in the 21st Century](#), Organization for Economic Cooperation and Development (OECD) and Open Markets Institute, April 24, 2020. This conference convened scholars and public officials to discuss how to ensure our global production systems are built to handle pandemics, natural disasters, political conflicts, and other shocks.
- [Barry Lynn Testimony](#) before the House Judiciary Committee on Reviving Competition, Part 6: Rebuilding Americas Economic Leadership and Combatting Corporate Profiteering
- [Barry Lynn Testimony](#) before the Senate Antitrust Sub-Committee on How Consolidation Resulted in the Baby Formula Shortage & How to Fix It
- [Barry Lynn Testimony](#) before the U.S. Senate Subcommittee on Fiscal Responsibility and Economic Growth on Promoting Competition, Growth, and Privacy Protection in the Technology Sector
- [“From Russia with Monopolies,”](#) Garphil Julien, *Washington Monthly*, February 25, 2022. Details how Russia is able to use its monopoly in fertilizer and grain for geopolitical purposes.
- [“Built to Break: The International System of Bottlenecks in the Era of Monopoly,”](#) Barry Lynn, *Challenge Magazine*, March/April 2011. In this article, we update the basic thesis from *End of the Line* to account for lessons from the Lehman crash of 2008 and the Tohoku disaster of March 2011. This is the most concise, comprehensive explanation of the nature and origins of the problem.
- [“Systemic Supply Chain Risk,”](#) Yossi Sheffi and Barry C. Lynn, *The Bridge*, Fall 2014. The first article in which an engineer recognized the systemic nature of international production arrangements and the potential for cascading crashes.
- [“Unmade in America: The True Cost of a Global Supply Line,”](#) Barry Lynn, *Harper’s*, July 2002. This is our first article on the subject of supply chain fragility and industrial interdependence, and it provided the seed for *End of the Line*.
- [“Shock Treatment: Building Resilient International Industrial Systems in 2030,”](#) Barry Lynn, in *Global Flow Security*, Erik Brattberg and Daniel Hamilton, editors, Johns Hopkins, 2015. This project was co-sponsored by a Swedish government project led by Tomas Ries and launched by Carl Bildt.
- [“War, Trade, and Utopia,”](#) Barry Lynn, *The National Interest*, Winter 2006. A straightforward discussion of the politics of industrial interdependence and dependence in a system marked by extreme concentrations of industrial capacity.

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Endnotes

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