A Supply Chain is Only as Strong as its Weakest Links: A Simple Methodology for Examining Imports in U.S. Supply Chains

September 2026

Erika Bethmann

David Coffin

Dominique Varier

Abstract

Disruptions to international trade due to regional and worldwide events like the onset of the COVID-19 pandemic have highlighted the vulnerability of modern supply chains and the importance of designing production processes with resilience and flexibility. Given the complexity of globalized trade—where tasks are increasingly modularized and distributed across international borders—the first step in evaluating and improving the strength of supply chains must be understanding potentially vulnerable points along the chain. This paper applies a simple approach to identifying vulnerable inputs along a supply chain at a national level by using a simple measure of sourcing concentration, the Herfindahl–Hirschman Index (HHI). By using the HHI methodology to examine the United States' automotive supply chain at the HTS 10-digit product level, this paper identifies eight vulnerable inputs and describes their significance to the U.S. industry in more detail. This paper uses the automotive industry to provide a concrete example of how this tool can identify potential vulnerabilities in a complex supply chain that could be broadened to additional sectors and country contexts.

A Supply Chain is Only as Strong as its Weakest Links: A Simple Methodology for Examining Imports in U.S. Supply Chains

Erika Bethmann, David Coffin, Dominique Varier

Office of Industry and Competitiveness Analysis and *Office of Economics*
U.S. International Trade Commission (USITC)
September 2026

This paper represents solely the views of the authors and is not meant to represent the views of the U.S. International Trade Commission or any of its commissioners. Please direct all correspondence to Erika Bethmann, Office of Economics, or David Coffin, Dominique Varier, Office of Industry and Competitiveness Analysis, U.S. International Trade Commission, 500 E Street, SW, Washington, DC 20436, email: erika.bethmann@usitc.gov, email: david.coffin@usitc.gov, email: dominique.varier@usitc.gov.

The authors would like to thank Samuel Goodman, Karen Thome, and Jeffrey Walling for their helpful comments and suggestions and David Lahrmer and Fernando Gracia for their support in production and publication.

Abstract

Disruptions to international trade due to regional and worldwide events like the onset of the COVID-19 pandemic have highlighted the vulnerability of modern supply chains and the importance of designing production processes with resilience and flexibility. Given the complexity of globalized trade—where tasks are increasingly modularized and distributed across international borders—the first step in evaluating and improving the strength of supply chains must be understanding potentially vulnerable points along the chain. This paper applies a simple approach to identifying vulnerable inputs along a supply chain at a national level by using a simple measure of sourcing concentration, the Herfindahl–Hirschman Index (HHI). By using the HHI methodology to examine the United States' automotive supply chain at the HTS 10-digit product level, this paper identifies eight vulnerable inputs and describes their significance to the U.S. industry in more detail. This paper uses the automotive industry to provide a concrete example of how this tool can identify potential vulnerabilities in a complex supply chain that could be broadened to additional sectors and country contexts.

Introduction

Although the recent COVID-19 pandemic highlighted the cascading impact of supply chain disruptions, identifying vulnerabilities and designing supply chains that can recover from disruptions has long been a goal of academics and industry stakeholders. On one hand, globalization has fostered increased connectivity among global economies, making the effective distribution of tasks within a production process a key determinant of competitiveness. On the other hand, increased distribution of tasks among more countries may have obscured the vulnerability of overly concentrated supply chains.

Dissecting supply chain vulnerability is an issue of national importance and requires deep product and industry knowledge.[1] The challenge of articulating supply chain vulnerability requires information from the private sector industry vantage point, to understand production functions and business operations, as well as the public sector policy makers—those who have the reach and responsibility to recognize trends at the industry and national level. Many firms engage in this type of analysis on a micro level, with a view only to their own products and production processes. While this analysis provides some specific insight on company trends, there is further insight to be drawn from a systematic analysis of supply chain resilience on a larger industry or national scale. This paper uses a simple approach to identify vulnerable inputs along a supply chain using the Herfindahl–Hirschman Index (HHI), a measure of sourcing concentration. This paper applies the HHI methodology to examine the United States' automotive supply chain at the HTS 10-digit product level, identifying six vulnerable inputs and describing their importance to the U.S. auto industry. It concludes with how identifying vulnerability among inputs in a global supply chain can help focus policymakers' efforts to build resiliency.

[1] See for example, the Office of the Director of National Intelligence's Supply Chain Risk Management page, which features several reports on protecting supply chains and increasing supply chain resilience.

Relevant Literature on Supply Chain Resilience

Supply chain resilience was formally conceptualized and defined in the early-2000s. In their multidisciplinary literature review, Ponis and Koronis find common elements in a number of definitions of supply chain resilience, and based on these common elements defined supply chain resilience as “the ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage.”[2] Supply chain resilience originated from definitions of resilience in other scientific disciplines, which implies maintaining structure or returning to previous quality and state of being following a strain or disruption.

Across various disciplines, resiliency takes on specific characteristics and is measured by various metrics. For example, in ecology, resilience has been defined both as the ability to maintain functional efficiency (how fast a system returns to equilibrium), and the ability to maintain functional existence (how much disturbance a system can withstand before changing state).[3] In the supply chain context, reliability of cost, speed, and input sourcing are often of paramount importance, such that it matters more that an order is satisfied than how or from where that order is satisfied. Based on this acceptance of nonlinear solutions, flexible sourcing and delivery are thus reasonable characteristics of resilient supply chains responding to disruption.[4]

Changes in inventory and sourcing strategies in the 1990s and 2000s affected resilience. Historically, producers mitigated against disruption by stocking inventory or diversifying their inputs.[5] Producers across various manufacturing sectors shifted toward just-in-time production in the 1990s and early 2000s as consumer preferences increasingly demanded changing styles and models with faster delivery times.[6] Without the ability to rely on inventory in the face of disruption, producers began to explicitly measure the expected costs of risk and recovery based on the severity and likelihood of potential disruption.[7] Some of the first methods for improving supply chain resilience therefore focused on increasing collaboration among different stakeholders in the supply chain to actively identify, plan, and engineer alternatives *in advance* of possible disruptions.[8]

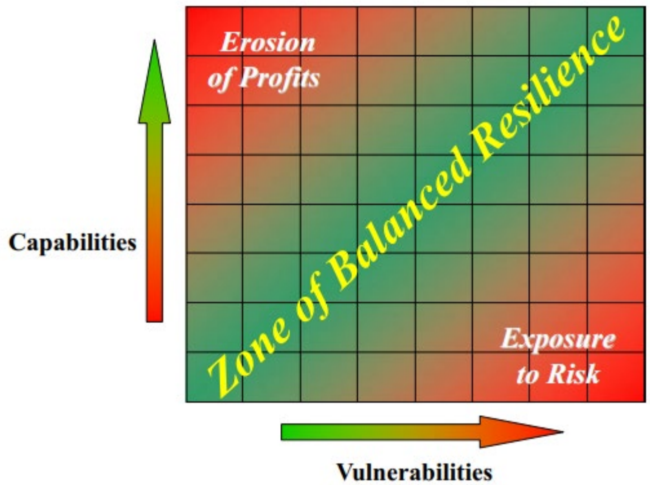
Using a theoretical approach, Pettit et al. developed a framework of seven vulnerability factors (40 sub-factors) and 14 capability or ‘recovery’ factors (71 sub-factors), which combined to form their concept of balanced resilience (figure 1). This theoretical approach is based on a review of related literature and a

---

[2] Ponis and Koronis, “Supply Chain Resilience,” August 21, 2012, 1.
[3] Ponis and Koronis, “Supply Chain Resilience,” August 21, 2012, 1–2.
[4] Fiksel, “Sustainability and Resilience,” October 2006, 16; Pettit, Fiksel, and Croxton, “Ensuring Supply Chain Resilience,” March 1, 2010, 12.
[5] Pettit, Fiksel, and Croxton, “Ensuring Supply Chain Resilience,” March 1, 2010, 3.
[6] Pettit, Fiksel, and Croxton, “Ensuring Supply Chain Resilience,” March 1, 2010, 3.
[7] Craighead et al., “The Severity of Supply Chain Disruptions,” March 2007.
[8] Pettit, Fiksel, and Croxton, “Ensuring Supply Chain Resilience,” March 1, 2010, 4.

series of focus groups with firm representatives. Their goal is to identify common supply chain vulnerabilities and techniques to anticipate potential disruptions and overcome them.[9]

Figure 1: Concept of balanced resilience, according to Pettit et al.



Source: Pettit, Fiksel, and Croxton, "Ensuring Supply Chain Resilience," March 1, 2010, 7.

This paper focuses on the geographic density of sourcing, i.e., *the spacing between nodes across a supply chain,* which is positively related to the severity of a supply chain disruption .[10] Pettit et al. find that turbulence, which encompasses geographical disruption, was the most frequently cited vulnerability, and that flexibility in order fulfillment and sourcing were the two most frequently cited capability factors within the firm focus groups, though the relative importance of each factor depends on the current resources and strengths of the particular firm.[11] Craighead et al. used a three-phase empirical research design comprised of interviews, focus groups and the review of archival records, to identify metrics through which practitioners can conceptualize and measure supply chain resilience, including supply chain density, complexity, and node criticality, along with mitigation capabilities of recovery and warning.[12]

The geographic density of sourcing relates directly to global supply chain vulnerability and resilience, a topic that has been written about extensively in the last decade. Concern about density and supply chain bottlenecks or chokepoints has led some to call for a "great supply chain reset" or a "second wave of the

[9] Pettit, Fiksel, and Croxton, "Ensuring Supply Chain Resilience," March 1, 2010, 2.
[10] Craighead et al., "The Severity of Supply Chain Disruptions," March 2007, 138–40.
[11] Pettit, Fiksel, and Croxton, "Ensuring Supply Chain Resilience," March 1, 2010, 10.
[12] In phase one, the authors conducted semi-structured interviews with key informants from different firms positioned across the supply chain and studied archival records of an auto producer. In phase two, the authors conducted more semi-structured interviews, but this time with high-level executives of nine firms in different industry sectors occupying different positions along a supply chain, selecting firms with different "supply chain and product flow characteristics." In phase three, the authors walked three focus groups through scenarios and responses to specific supply chain disruptions and recoveries. Craighead et al., "The Severity of Supply Chain Disruptions," March 2007, 136–37.

globalized supply chain."[13] Following the COVID-19 pandemic, disruptions to key manufacturing hubs, supply chain bottlenecks, and growing concerns about a general overreliance on imported inputs from China, firms are increasingly shifting away from simple, linear, low-cost, outsourcing-based models. Firms are proactively blending global and regional models—prioritizing the ability to pivot and reconfigure partnerships to address resilience and agility, particularly in advance of potential disruptions from a key source.[14]

Identifying potential chokepoints and instances of overreliance in global manufacturing supply chains is a key part of building a more resilient supply chain. Thus, interest in analytical techniques that identify potential vulnerabilities in upstream nodes in manufacturing supply chains has grown. Although tools that measure the stability and potential for future supply chain disruptions exist – like the Global Supply Chain Pressure Index (GSCPI) from the Federal Reserve Bank of New York[15]– there are no tools available yet that provide a quick and simple analysis and visibility into upstream supply chains regarding potential chokepoints and vulnerabilities in particular sectoral and geographical areas.[16]

Greater visibility and understanding of a supply chain helps companies assess potential vulnerabilities and improve their responsiveness and recovery rates. Yogaananthan describes the benefits to firms of gaining visibility into their supply chains as one strategy to increase resiliency.[17] Crosnier and Rey-Marston also extol the benefits of supply chain visibility for resiliency.[18] Numerous scholars approached the measurement of resilience using complex, multi-dimensional modeling that often focuses on the impact on a single firm.[19] There are few firm-specific studies and they are often confidential given their reliance on proprietary data. This paper seeks to examine supply chains at a national level using publicly available data and relatively simple methods, to identify areas where overreliance on a single country could affect the resiliency of an entire supply chain.

Lemmers et. al. developed a novel methodology that combines supply chain mapping with risk analysis to identify key vulnerabilities in a given supply chain. They integrated information from multiple input-output and supply-use tables to derive inter-industry linkages across countries in the value chain at a granular HS-6 product level.[20] Using the Dutch pharmaceutical industry as a case study, they calculate a

---

[13] Govshteyn, "Navigating the Great Supply Chain Reset," October 12, 2023; Scaff, "Create the New Global Supply Chain," September 22, 2022.
[14] Scaff, "Create the New Global Supply Chain," September 22, 2022; Ashraf et al., *Resilience Redefined: From Readiness to Reinvention*, June 11, 2025, 21.
[15] The GSCPI combines measures of cross-border transportation costs—constructed from data on the Baltic Dry Index, the Harpex index, and the U.S. Bureau of Labor Statistics—with variables from the IHS Markit Purchase Manager Index (e.g., delivery time, backlogs, purchased stocks, etc.) to create a single, public, global indicator. Although this index incorporates some country-specific data from seven major economies, the final index is at the global level and not customizable to different regions or sectors. Federal Reserve Bank of New York, "Global Supply Chain Pressure Index," accessed May 20, 2024; Benigno et al., "The GSCPI," May 2022, 2–3.
[16] Alicke et al., "Supply Chain Disruption and Resilience," August 26, 2022.
[17] Yogaananthan, *Building Resilient Supply Chains*, 2020.
[18] Crosnier and Rey-Marston, "How Supply Chain Visibility Delivers Resilience," 2022.
[19] Munoz and Dunbar, "On the Quantification of Operational Supply Chain Resilience," November 17, 2015; Li et al., "A New Resilience Measure for Supply Chain Networks," January 2017; Hosseini, Ivanov, and Blackhurst, "Conceptualization and Measurement of Supply Chain Resilience in an Open-System Context," December 2022.
[20] Lemmers et al., "Which products are traded in your supply chain?," accessed December 24, 2024, 5–8.

cumulative risk indicator that consolidates sub-indicators including import value, world market and Netherlands import concentration via the Herfindahl-Hirschman index (HHI), the extra-EU share of EU imports and the substitution ratio for such imports, and centrality (an indicator derived from network analysis to identify crucial producers within a trade network).[21] Their approach shares similarities with the methodology laid out in this paper in the usage of the HHI and various thresholds to identify vulnerabilities at a product level. However, Lemmers et. al. requires significant input-output table analysis, which this paper substitutes for industry knowledge and a pre-defined list of auto sector-specific inputs in an effort to make the methodology more accessible to the public.

Methodology: Finding Vulnerabilities in an Upstream Supply Chain Using a Measure of Concentration

Description of the U.S. Automotive Sector and Supply Chain

This paper focuses on the automotive industry for a few key reasons: its size, its complexity, and recent examples of how supply chain challenges can significantly affect production. The U.S. automotive industry is the largest manufacturing industry in the United States, accounting for 11 percent of U.S. manufacturing output in 2023, 15 percent of U.S. imports, and 8 percent of U.S. exports.[22] The U.S. automotive industry directly employs 1.1 million people in vehicle and parts production, and a further 2.1 million are employed in vehicle and parts dealerships.[23]

The U.S. automotive industry's supply chain is complex and multi-layered. Two dozen vehicle manufacturers purchase thousands of parts from hundreds of suppliers for each vehicle model. The industry generally divides suppliers into three categories:

Tier 1 – direct supplier of systems to vehicle manufacturers

Tier 2 – supplier of parts to Tier 1 suppliers

Tier 3 – suppliers of natural resources to vehicle manufacturers, Tier 1's and Tier 2's.

This complexity presents a challenge for analyzing the supply chain, as there are many potential points of failure, and few participants (if any) have a clear view of their entire supply chain.[24] Shortages in components and inputs can slow or stop production if there are not suitable replacements available. For example, automotive chips make up a small percentage of the value of a car, yet shortages in such chips

[21] Lemmers et al., "Which products are traded in your supply chain?," accessed December 24, 2024, 8–9.
[22] GDP by Industry, "BEA Interactive Data Application, Gross Output by Industry," accessed March 2, 2023; USITC DataWeb/Census, list of HTS subheadings corresponding to light vehicles, heavy trucks, and automotive parts are in appendix F of the USITC's USMCA Automotive ROOs 2023 report, accessed January 24, 2025.
[23] U.S. Department of Labor, Bureau of Labor Statistics, "Automotive Industry," accessed December 1, 2022.
[24] Supply chain visibility beyond direct suppliers is particularly limited for many firms. Adams, "What Is Supply Chain Visibility & Why Does It Matter?," November 25, 2024.

prevented vehicle manufacturers from producing millions of units in 2020–22.[25] Another example is shortage of a pigment called "Xirillac" after the Fukushima earthquake. This pigment gives black, red, and other colors their metallic shine. When the only plant producing the pigment was evacuated after Fukushima and temporarily halted production, it led to vehicle producers restricting production of vehicles in those colors.[26]

Data

The authors used the U.S. Department of Commerce's exhaustive list of automotive parts HTS statistical codes to define the scope of the industry. Major suppliers of automotive parts to the United States include Mexico (39 percent), China (10 percent), Canada (10 percent), Japan (9 percent), the EU (9 percent) and Korea (8 percent).[27] This paper analyzes trade flows from the EU both in the aggregate, and as separate individual countries for two reasons: first, the EU is a major vehicle and parts producer; second, because of its importance, the authors wanted to understand how separating the countries individually might affect the analysis. When analyzing separately, Germany and Italy together accounted for over 50 percent of all U.S. automotive parts imports from the EU.[28]

This paper uses annual U.S. import data from the U.S. International Trade Commission's DataWeb for statistical reporting numbers listed in the Department of Commerce Auto Parts List as of 2023, for the years 2012–22.[29] The U.S. Department of Commerce maintains an automotive parts list that contains 269 distinct HTS10 statistical reporting numbers.[30] In 2022, imports under these statistical reporting numbers totaled $176 billion from 227 individual countries and 17 different regions.[31] Top automotive parts supplier countries by dollar value included USMCA partner countries Mexico (largest supplier) and Canada (third), but also China (second).[32]

The Herfindahl–Hirschman Index

The Herfindahl-Hirschman Index (HHI) is a simple, frequently used measure of market concentration. For this paper, HHI calculations measure trade concentration in the supply chain for HTS10 statistical code. For example, to calculate the country level of geographic concentration among U.S. imports, the following formula is used:

$$HHI^i = {s_1}^2 + {s_2}^2 + {s_3}^2 + \cdots {s_n}^2$$

[25] Semiconductor chips reportedly cost $550 per car on average. Assuming vehicles cost $20,000 to $30,000 would put the value of semiconductors at 2-3 percent of the value of the vehicle. Compound Semiconductor, "Chips per Car to Rise," December 5, 2022; Coffin et al., *The Roadblocks of the COVID-19 Pandemic*, June 2022.

[26] Seetharaman, "Automakers Face Paint Shortage after Japan Quake," March 26, 2011.

[27] Staff calculations based on USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024.

[28] U.S. auto parts imports from Germany accounted for 43 percent of all U.S. imports from the EU (11 percent for Italy). Staff calculations based on USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024.

[29] U.S. Department of Commerce, "Automotive Parts Tariff Codes," 2023.

[30] The HS chapters in the Department of Commerce list of automotive parts are Chapters 38, 40, 68, 70, 73, 83, 84, 85, 87, 90, 91, and 94. U.S. Department of Commerce, "Automotive Parts Tariff Codes," 2023.

[31] USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024.

[32] USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024.

$s_n =$ the market share percentage of country n in U.S. imports of HTS10 statistical reporting number i

HHI calculations can be used to identify products which are not imported from a wide array of sources. Such segments of the supply chain may be less resilient, as disruption to production or trade from a single country or region would be challenging to replace. The HHI function measures concentration within a product's supply at the HTS10 statistical reporting number level. The HTS10 statistical reporting level provides the highest level of detail available for U.S. imports, allowing precise identification of vulnerable products along U.S. supply chains. HHI values range from 0 to 10,000, with lower values indicating a less concentrated supply for a product.[33] Generally, HHI values less than 1,500 represent an unconcentrated source of supply, while 1,500-2,500 indicates a moderate level of trade concentration. Greater than 2,500 are considered highly concentrated, indicating few sources of supply.[34] Greater than 5,000 are considered extremely concentrated, and rely on a very limited number of sources.

To illustrate this method with an application to the automotive sector, this paper calculated three HHI values for each of the 269 automotive inputs on the DOC list:

a) **Import HHI:** Using U.S. import data, calculate the HHI value for each product at the country level to measure the geographic concentration of individual U.S. automotive input statistical codes.
b) **Regional HHI:** Using U.S. import data, calculate the HHI value for each product at the regional level[35] to measure the geographic concentration of individual U.S. automotive input statistical codes.[36]
c) **Export HHI:** Using global trade export data, calculate the HHI value for each HS subheading at the country level to measure the geographic concentration of global exports of these HS subheadings.

Import HHI and Regional HHI values for U.S. import data from 2012, 2015, 2018, 2020, and 2022 were calculated, while Export HHI values were calculated using global trade data from the same years. These five years provide insight into the changes in HHI values between 2012 and 2022 for inputs identified as vulnerable in 2022.[37] This analysis can be done using data with closer intervals across any time frame depending on the context of the sector and issues being investigated. The top three largest sources of imports by country and their share of total U.S. imports were also identified for each product at the

[33] When calculating the HHI value, market share percentages are expressed as whole numbers out of 100.
[34] Goodman, "A Method of Estimating Global Supply Chain Risk," January 2023, 5; Netherlands, "Import Concentration," accessed November 17, 2025; Bruckner, "Measuring Export Concentration for Identifying Least Developed Countries," October 2023, 7.
[35] Regions in the U.S. import data include Australia and New Zealand, Central Asia, Eastern Asia, Eastern Europe, Latin America and the Caribbean, Melanesia, Micronesia, Northern Africa, Northern America, Northern Europe, Polynesia, South-eastern Asia, Southern Asia, Southern Europe, Sub-Saharan Africa, Western Asia, and Western Europe.
[36] Automotive parts data was combined with a regional mapping of UN geo-scheme regions and sub-regions based on the exporting country listed in the U.S. import data to allow for the calculation of regional and sub-regional level HHI values. GitHub, "ISO-3166 Country and Dependent Territories Lists with UN Regional Codes," December 8, 2020; UNSD, "Standard Country or Area Codes for Statistical Use (M49) Methodology," accessed May 29, 2024.
[37] These five years were chosen to provide a sample from the period of 2012 to 2022, with more weight on recent years.

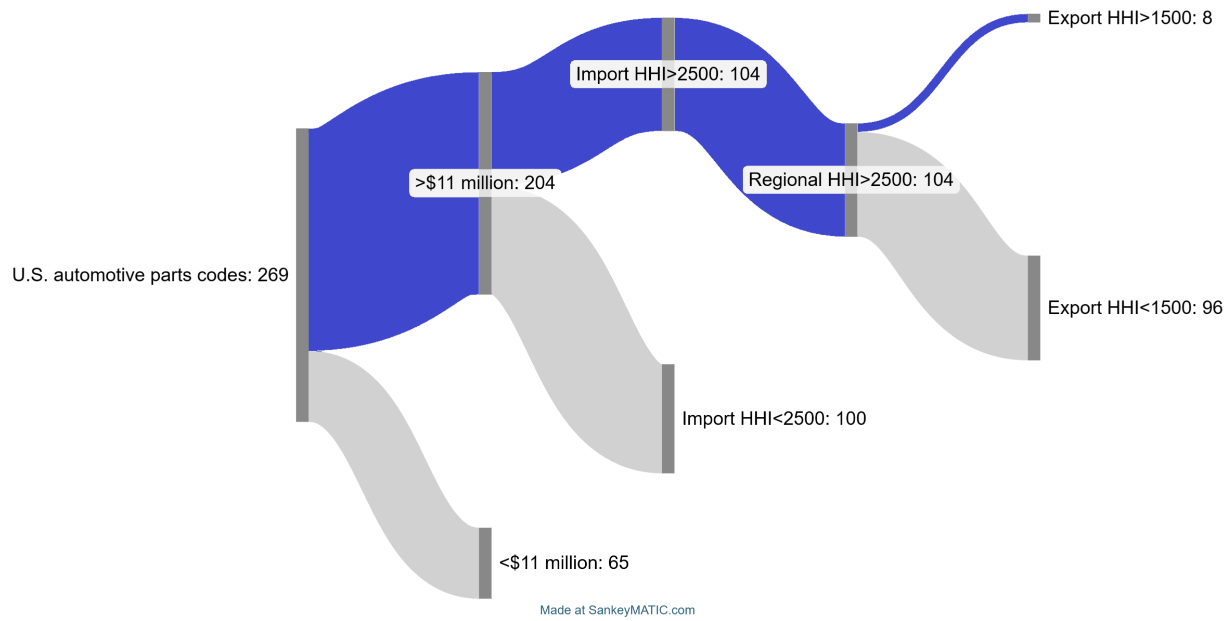
HTS10 statistical reporting number level. Global export data were used to identify the largest exporter by country at the HS6 level and their share of global exports as a percentage.[38]

Identifying Vulnerabilities in the U.S. Automotive Sector:

This paper uses HHI values to identify automotive statistical reporting numbers where the United States appears to be reliant on a single country that may increase the vulnerability of the supply chain. To identify potentially vulnerable portions of the U.S. automotive upstream supply chain, this paper takes the 269 automotive parts at the HTS10 level in the Department of Commerce list and filters them with the following criteria (figure 2):

1) U.S. imports (HTS 10) of $11 million or more in 2022 (economic significance)[39];
2) U.S. imports (HTS 10) by country with an HHI value of 2,500 or more in 2022 (Import HHI);
3) U.S. imports (HTS 10) by region with an HHI value of 2,500 or more in 2022 (Regional HHI);
4) Global exports (HS6) by country with an HHI value of 1,500 or more in 2022 (Export HHI).

Figure 2: The filtering process for finding vulnerable import products



Sources: Staff calculations based on trade data.

For step 1, a U.S. import value of $11 million or greater was chosen as the threshold for economic significance to identify automotive parts at the HTS10 level that the United States imports in significant

[38] The HS6 statistical reporting level is the highest level of product reporting available the global export data for all reporting countries; limiting the calculation and analysis of Export HHI as a proxy measure to the HS6 level rather than being calculated at the HTS10 level, as was done for Import HHI and Regional HHI values.

[39] $11 million is a round number representing a little more than a dollar per vehicle produced in the United States. Something imported less than that would likely not have a significant impact.

amounts. This filtration process aims to pinpoint automotive parts that pose the greatest risk of disrupting the U.S. automotive supply chain. By identifying and establishing a baseline threshold for the U.S. import value of significant inputs, this allows for a targeted identification of what upstream inputs are high risk. The specific baseline can vary depending on import data and industry-specific dynamics. For instance, this paper selected a U.S. import value threshold of $11 million by using the first quartile of import values for the 269 automotive parts, as detailed in table 1 below.[40]

For steps 2 and 3 the authors used 2,500 as the HHI threshold. This threshold is at the higher end of the range most commonly used in the literature. The authors chose this threshold because the import data was at the disaggregated HTS10 level, and more likely to produce high HHI levels.

Table 1: Summary statistics for the U.S. import value of the 269 automotive parts identified at the HTS10 statistical reporting level, based on 2022 U.S. import data

U.S. imports in millions of dollars.

1st Quartile	Median	3rd Quartile	Average	Range
11,537,700	120,163,705	561,809,568	654,776,495	[0 - 16,163,930,277]

Sources: USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024.

For step 4 outlined above, the authors conducted sensitivity analysis on EU country groupings and HHI value thresholds.[41] Global export data either report the EU member states as 27 individual reporters or group them as a single trading bloc; the latter excludes internal trading among EU members. Different sources also recommend different HHI concentration thresholds, with some preferring 2,500 (or highly concentrated) and some preferring 1,500 (moderately concentrated).[42] HHI export values' threshold level is important, because it can significantly affect the number of potentially vulnerable automotive statistical codes identified.

To compare EU country groupings, the authors calculated Export HHI values with EU member states individually and in the aggregate. Then the authors determined how many HTS10 statistical reporting numbers met the vulnerability criteria with both groupings. The authors also compared the number of statistical codes identified as vulnerable if the Export HHI threshold were greater than or equal to 2,500 instead of 1,500 (in line with the thresholds used for steps 2 and 3). Table 2 shows how many HTS10 statistical reporting numbers met the criteria with Export HHI including individual EU members and the EU as a single trading block.

[40] This step removed 36 statistical codes with an import HHI higher than 2,500, including vehicle bodies of other passenger vehicles and certain beam hanger brackets. A complete review of U.S. automotive supply chain vulnerability would possibly have a lower threshold, or no threshold, instead filtering out many of the lower total imports of parts due to low import penetration and/or low potential impact.

[41] Sensitivity analysis was not done on HS aggregation, on the assumption that manufacturers would not be able to switch from parts in one statistical code to parts in another statistical code.

[42] Sources classify 1,500 to 2,500 as moderately concentrated, and greater than 2,500 as highly concentrated. Goodman, "A Method of Estimating Global Supply Chain Risk," January 2023, 5; Netherlands, "Import Concentration," accessed November 17, 2025; Bruckner, "Measuring Export Concentration for Identifying Least Developed Countries," October 2023, 7.

Table 2: Number of HTS10 statistical reporting numbers identified as vulnerable based on different global trade datasets used and Export HHI filters, based on 2022 data

Thresholds	Individual EU members	EU as a single trading bloc
Export HHI > 2500	1	3
Export HHI > 1500	8	62

Sources: USITC DataWeb/Census, Automotive Parts Tariff Codes, accessed March 11, 2024; S&P Global, Global Trade Atlas, HS subheadings associated with Automotive Parts Tariff Codes (March 11, 2024).
Note: More information on table 2 and the HTS10 statistical reporting numbers identified as vulnerable if the EU was identified as a single trading block can be found in Appendix A.

Disaggregated EU country data and a threshold of 1,500 were selected for inclusion in the criteria. Incorporating individual EU country-trade better reflects global trading dynamics in the automotive sector, given that Germany and Italy alone supply more than half of the United States' imports of auto parts from the EU. A less strict Export HHI threshold of 1,500 instead of 2,500 is used because Export HHI is a rough proxy for the availability of alternative sources, and it provides a wider group of products to analyze.

The filtration process above found eight potentially vulnerable HTS10 statistical reporting numbers for U.S. automotive parts imports (table 3). These eight statistical reporting numbers represent 3.4 percent ($6.0 billion) of U.S. automotive parts imports in 2022. Among the eight automotive inputs identified as vulnerable in the U.S. supply chain, imports of catalytic converters (HTS 8421.32.0000) and lithium-ion batteries (HTS 8507.60.0010) are particularly large. Imports of these two components represented nearly five billion dollars in 2022. Out of the 269 identified automotive inputs, catalytic converters and lithium-ion batteries ranked as the 16th and 18th most imported by the United States in 2022, emphasizing their critical role in the industry. The rest of this paper discusses trade and mitigating factors for each of the eight statistical reporting numbers in more detail.

Table 3: Potentially vulnerable HTS10 statistical reporting numbers in the U.S. automotive supply chain, based on 2022 import/export data
HHI in index value; U.S. imports in millions of dollars.

HTS10	Product Description	Import HHI	Regional HHI	Export HHI	Total U.S. Imports
8421.32.0000	Catalytic converters	3,218	3,403	1,759	$ 2,743
8507.60.0010	Lithium-ion batteries	6,446	7,728	2,746	$ 2,196
8425.49.0000	Jacks	3,749	4,087	1,732	$ 373
8527.29.4000	Certain Radios	9,771	9,772	1,583	$ 312
8527.29.8000	Certain Radios	6,842	6,855	1,583	$196
8539.21.2040	Tungsten halogen lamps	5,186	5,507	1,721	$ 85
8517.14.0020	Radio telephones for motor vehicles	4,226	5,348	2,082	$ 59
6813.89.0050	Friction material, not brake linings	3,268	3,996	1,523	$ 19

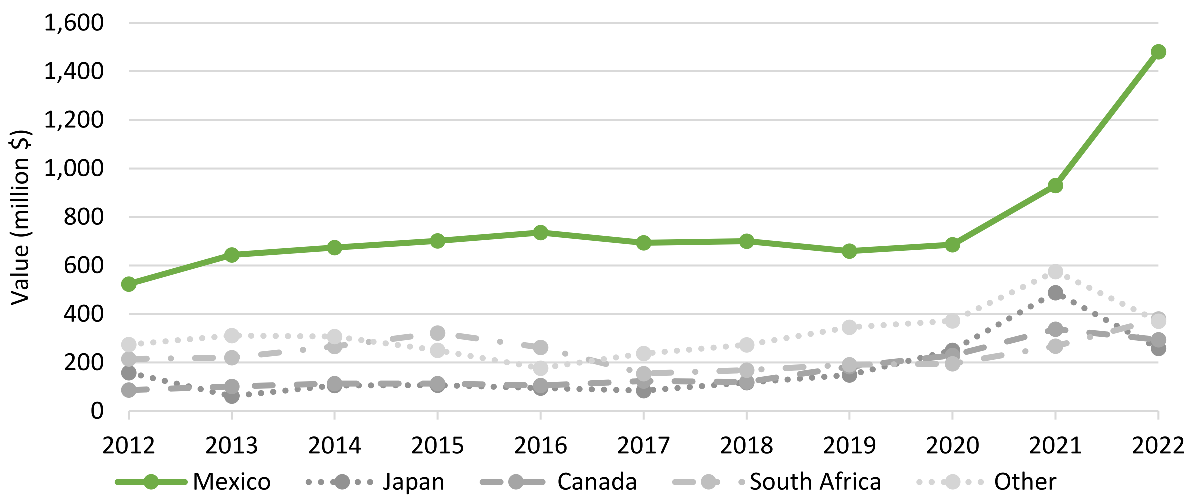
Sources: U.S. Department of Commerce Automotive parts list. HHI calculated based on data from USITC, DataWeb/Census (March 11, 2024); S&P Global, Global Trade Atlas, (March 11, 2024).
Note: This analysis relies on differentiated 10-digit statistical codes. It cannot be used as easily to analyze products (such as semiconductors) that aggregate disparate products into statistical codes.

Catalytic converters for motor vehicles (HTS 8421.32.0000 and 8421.39.4000)[43]

Despite a significant increase in 2022 imports, U.S. catalytic converter imports remained concentrated throughout the period, with Mexico supplying the largest share (figure 3). USMCA's automotive rules of origin, which entered into force in mid-2020 and increase the amount of North American content needed for a vehicle to qualify for duty-free treatment within the USMCA region, may have driven the significant increase in U.S. imports from Mexico in 2021 and 2022.[44] USMCA's regional value content requirement increased 12.5 percentage points over the previous agreement (NAFTA).[45] A catalytic converter converts hazardous combustion gases into water vapor and carbon dioxide as part of a vehicle's exhaust system.[46]

Figure 3: U.S. imports of catalytic converters for motor vehicles, 2012–22

In millions of dollars.



Source: USITC DataWeb/Census, HTS statistical reporting numbers for catalytic converters, 8421.32.0000 and 8421.39.4000, accessed March 11, 2024.
Note: 2012 to 2021 shows the older statistical code (HTS 8421.39.4000), which went to zero in 2022 and was replaced by HTS 8421.32.0000.

In 2022, the concentration of U.S. imports of catalytic converters for automobiles was relatively high. The Import HHI value for HTS 8421.32.0000 in 2022 was 3,218, which indicates little diversity in U.S. import sources. That pattern continues with the Regional HHI, which has a value of 3,403, further indicating

[43] In 2022, the World Customs Organization (WCO) separated catalytic converters from machinery and apparatus for purifying gases (HS 8421.39) to create a separate subheading for catalytic converters (HS 8421.32). The United States already had a single statistical reporting number for catalytic converters (HTS 8421.39.4000). Figure 3 shows data from 2012 to 2021 with the older statistical code (HTS 8421.39.4000), which went to zero in 2022, and was replaced by HTS 8421.32.0000.

[44] USITC, *USMCA Auto ROO 2025*, June 2025, 46, 124.

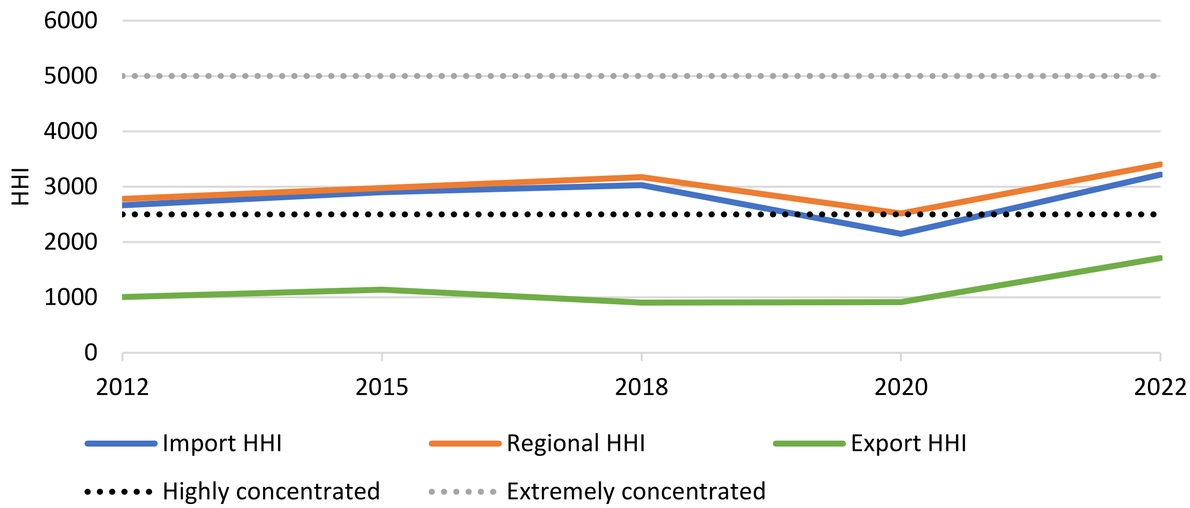
[45] USITC, *USMCA: Likely Impact on the U.S. Economy and on Specific Industry Sectors*, April 2019.

[46] UTI, "What Is a Catalytic Converter and What Does It Do?," January 6, 2021.

little import diversity for U.S. imports of catalytic converters at the regional level (figure 4). Imports under the old statistical reporting number (8421.39.4000), appear to be similarly concentrated.

Figure 4: HHI for catalytic converters, 2012–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS statistical reporting numbers for catalytic converters, 8421.32.000 and 8421.39.4000, accessed March 11, 2024; and export data from S&P Global Market Intelligence, "HS 8421.32 and HS 8421.39," accessed May 2, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

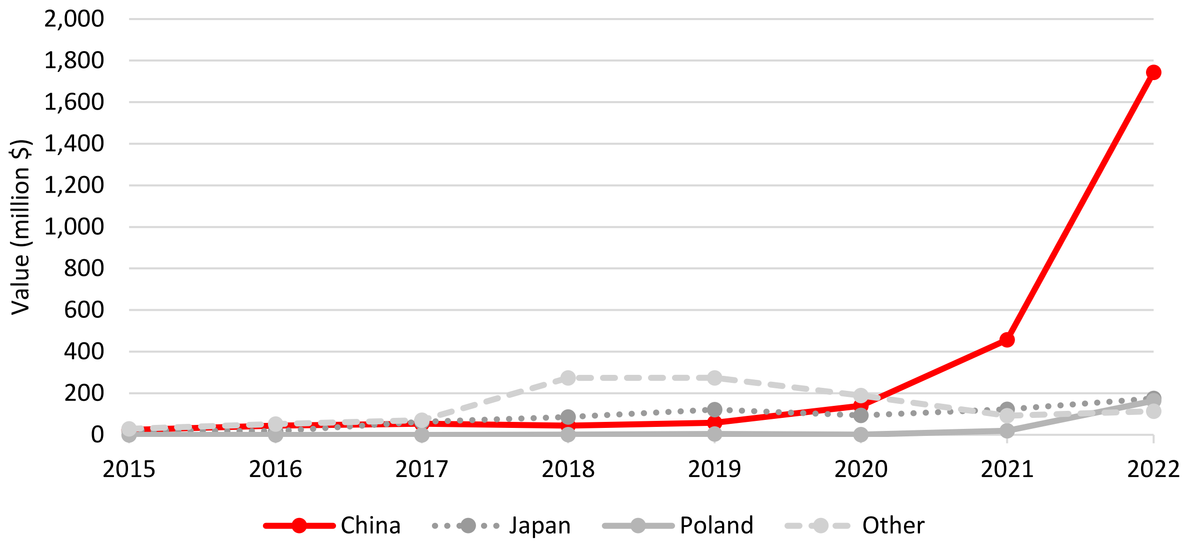
Lithium-ion batteries for motor vehicles (HTS 8507.60.0010)

U.S. imports of lithium-ion batteries for motor vehicles have increased substantially in the last four years to support U.S. electric vehicle (EV) production. This increase in dependence on imported lithium-ion batteries is largely due to the fact that U.S. EV production has outpaced U.S. lithium-ion battery production. However, U.S. lithium-ion battery production capacity is expected to expand from 70 gigawatt hours (GWh) in 2021 to more than 900 GWh in 2027.[47] As U.S. lithium-ion battery production increases, U.S. lithium-ion battery import increases may slow significantly or even decline. China was the leading source of imports in 2021 and 2022, greatly outpacing all other sources (figure 5).

[47] International Energy Agency (IEA), "Global Supply Chains of EV Batteries – Analysis," July 2022, 33; Bhutada, "Visualizing China's Dominance in Battery Manufacturing (2022-2027P)," January 19, 2023.

Figure 5: U.S. imports of lithium-ion batteries for motor vehicles, 2015–22

In millions of dollars.



Source: USITC DataWeb/Census, HTS statistical reporting number 8507.60.0010, lithium-ion batteries of a kind used as the primary source of electrical power for electrically powered vehicles of subheadings 8703.40, 8703.50, 8703.60, 8703.70 or 8703.80, accessed March 11, 2024.

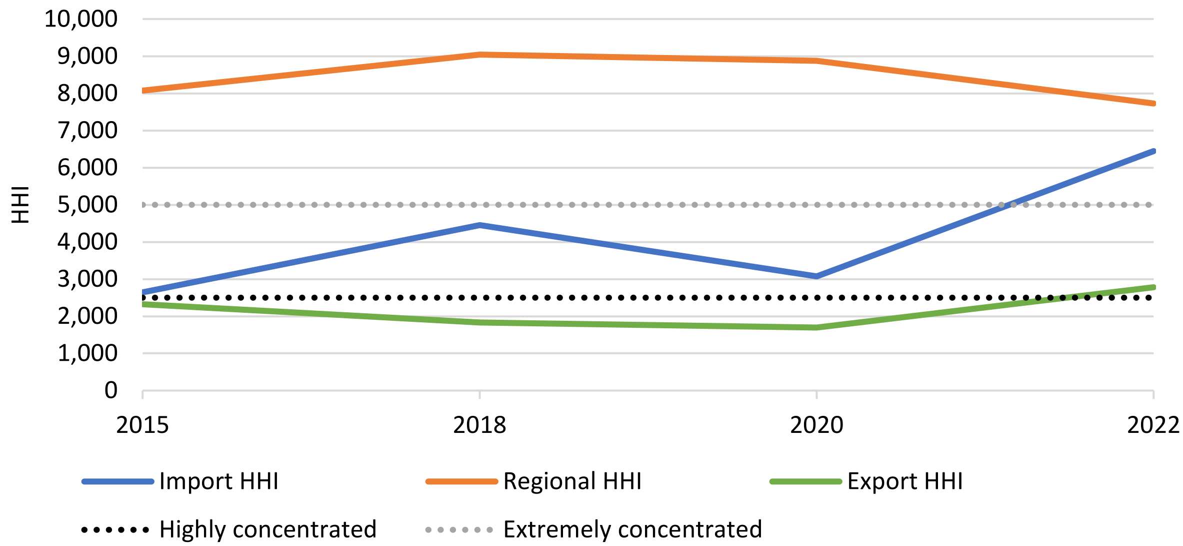
While imports of HTS 8507.60.0010 have increased, so has the product's concentration. From 2015 to 2022 the Import HHI for lithium-ion batteries increased from just over 2,500 to over 6,400. The increase in Import HHI reflected China becoming the leading supplier, accounting for over 79 percent of U.S. lithium-ion battery imports in 2022. The Regional HHI for lithium-ion batteries was even more highly concentrated throughout the same period, likely because Japan and South Korea, both located in the Eastern Asia subregion, were the other top global sources. However, the Regional HHI actually declined over the period, likely because of increased imports from EU countries such as Poland (figure 6). China was also the largest global exporter, accounting for over 45 percent of global exports, leading to lithium-ion batteries' Export HHI of 2,561. Interestingly, China accounts for a much larger share of global production capacity (over 70 percent) than its export share.[48]

The concentration of imports at the statistical reporting number level may overemphasize the vulnerability of the lithium-ion battery supply chain because of its focus on battery packs. Lithium-ion batteries for motor vehicles are made up of battery packs that include dozens to hundreds of battery cells, depending on type. Most of the value-added is in cell production, and pack assembly can be set up relatively easily in close proximity to vehicle assembly.[49] Imports of lithium-ion battery cells fall under 8507.9080 (lithium-ion battery parts). South Korea is the top U.S. source of such imports. U.S. imports classified in that statistical reporting number are highly concentrated, but on a global level, the exports in 8507.90 are not, meaning the United States may be able to acquire cells from another source if packs from China are not available.[50]

[48] Bhutada, "Visualizing China's Dominance in Battery Manufacturing (2022-2027P)," January 19, 2023.
[49] Klier and Rubenstein, "The Emerging Geography of Electric Vehicle Production," July 2024.
[50] The Import HHI value for 8507.9080 is 3,627, while the Export HHI for 8507.90 was 1,438 in 2022.

Figure 6: HHI for lithium-ion batteries for motor vehicles, 2015–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS statistical reporting number 8507.60.0010, accessed March 11, 2024; and export data from S&P Global Market Intelligence, "HS subheading 8507.60," accessed May 2, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

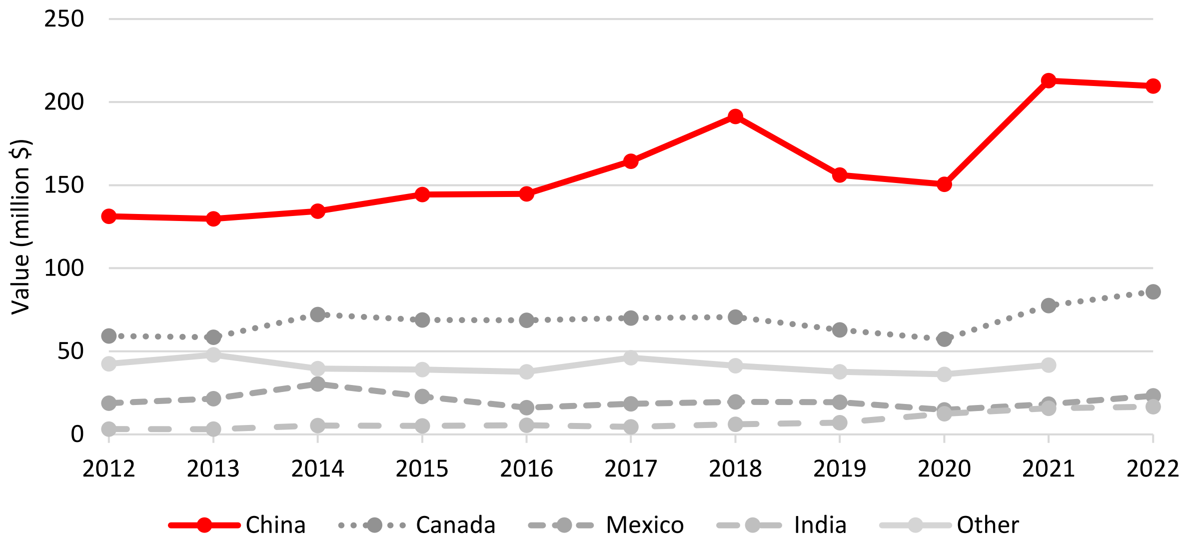
Jacks (HTS 8425.49.0000)

U.S. hydraulic jack imports are potentially vulnerable, but they are not required to be included in new vehicles. As a part that is not required, their concentration may introduce less vulnerability to the U.S. automotive supply chain. U.S. jack imports originated primarily in China, which made up over 56 percent of U.S. imports in 2022 (figure 7), a 5.1 percentage point increase from 2012.[51] U.S. jack imports from China increased significantly during the period, growing from just over $131 million in 2012 to nearly $210 million in 2022 (60 percent increase in value). This increase was driven by growing volume, as cost per unit from China grew more slowly (20.7 percent) than unit cost for U.S. jack imports (31.1 percent).

[51] USITC DataWeb/Census, HTS subheading 8425.49.0000, Jacks, accessed May 2, 2024.

Figure 7: U.S. imports of jacks, 2012–22

In millions of dollars.

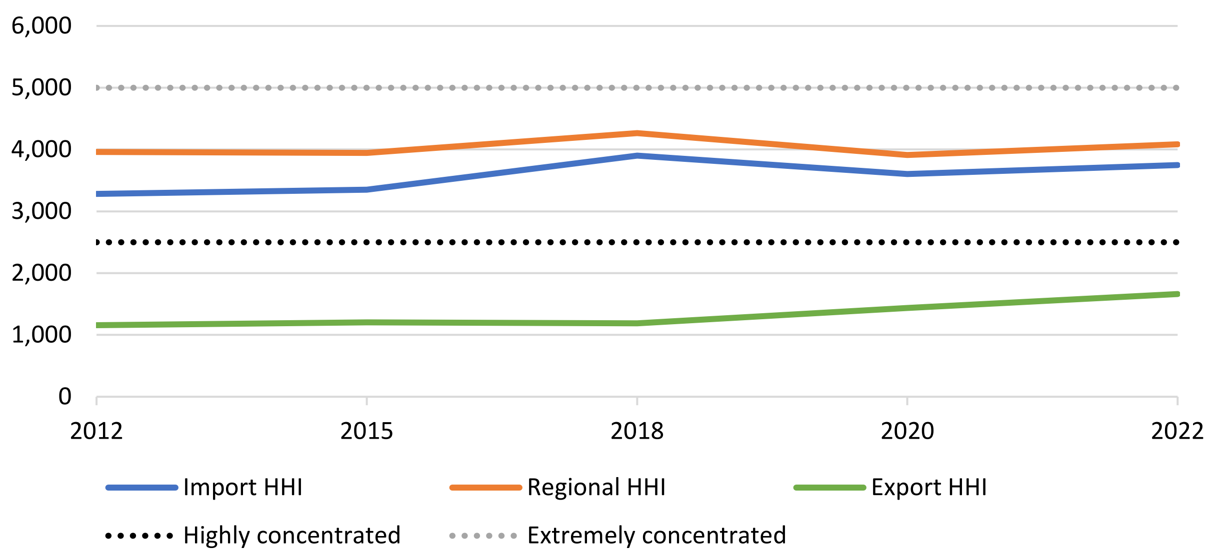


Source: USITC DataWeb/Census, HTS subheading 8425.49.0000, Other jacks, accessed May 2, 2024.

The Import and Regional HHIs for jacks were highly concentrated throughout the period. The Import HHI increased from nearly 3,300 to nearly 3,750 while the Regional HHI only increased slightly from less than 4,000 to nearly 4,100 (figure 8). Export HHI was significantly lower, staying beneath 2,000 throughout the period, meaning exports were not highly concentrated for any year.

Figure 8: HHI for jacks, 2012–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS subheading 8425.49.0000, accessed May 2, 2024; and export data from S&P Global Market Intelligence, "HS subheading 8425.49," accessed May 2, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

Two factors may reduce the riskiness of the concentration of jack imports. The first is that a jack is not a required vehicle part. As of 2022 nearly a third of new vehicles came with a patch kit instead of a jack and a spare tire to reduce cost and weight.[52] Second, because a jack is not a required part, the share of aftermarket jacks may be higher. Such jacks are not a part of the new vehicle supply chain, and disruption in their supply would not affect new vehicle production.

Certain radios for motor vehicles (HTS 8527.29.4000 and 8527.29.8000)

Certain radios for motor vehicles include FM only, AM/FM only, and others, but exclude satellite radios and radios that incorporate cassettes or optical discs.[53] They make up less than 20 percent of U.S. motor vehicle radio imports.[54] Vehicle manufacturers could likely substitute other radio types if imports of radios in this section were disrupted. The transition away from radios incorporating optical discs (CDs) has fueled growth of such radio imports. U.S. imports of radios for motor vehicles rapidly increased in the past decade, from $37 million to $312 million between 2012 and 2022 for HTS 8527.29.4000, and from $23 million to $196 million for HTS 8527.29.8000 (figure 9)—an increase of 746.5 percent and 736.1 percent over ten years (23.8 percent and 23.7 percent per annum, respectively).

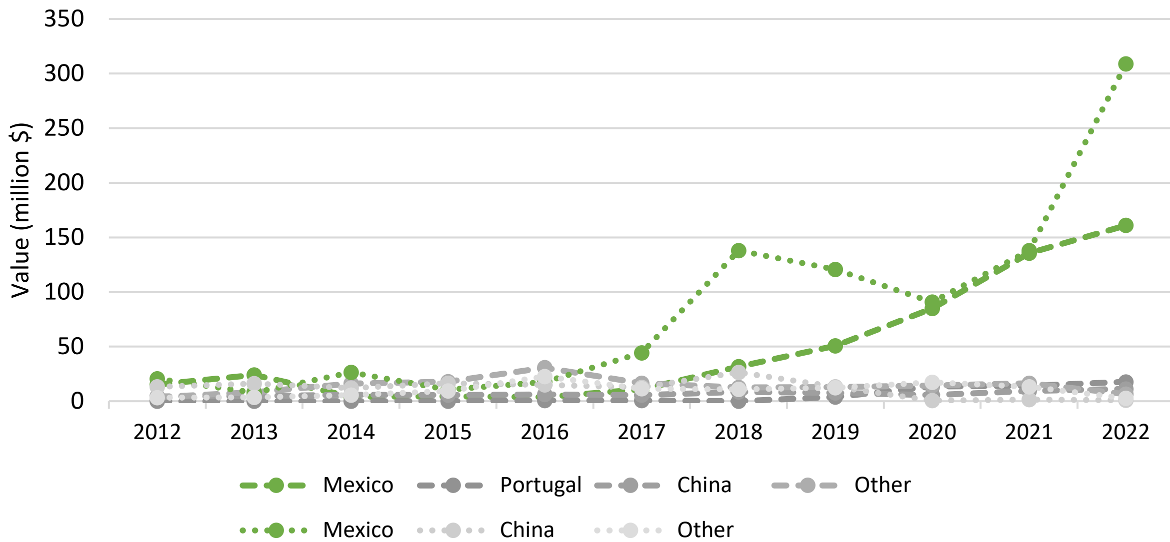
[52] Bohr, "Why More Cars Have a Tire Inflator Kit," April 15, 2022.

[53] USITC DataWeb/Census, HTS subheading 8527.29.4000, Jacks, accessed May 2, 2024.

[54] The category including satellite radios (HTS 8527.21.4080) made up over 75 percent ($2.2 billion) of U.S. motor vehicle radio imports, but the Export HHI fell below the threshold of concern for this exercise.

Figure 9: U.S. imports of radios for motor vehicles, 2012–22

In millions of dollars.



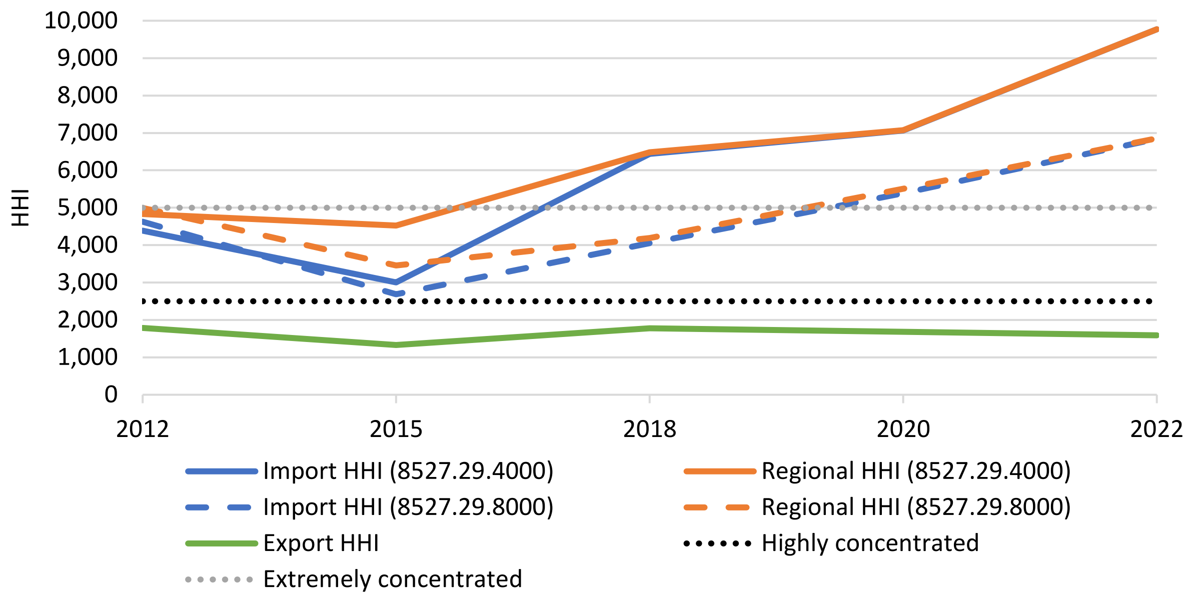
Source: USITC DataWeb/Census, HTS statistical reporting numbers 8527.29.4000, Radiobroadcast receivers not capable of operating without an external source of power, of a kind used in motor vehicles that are for FM only or AM/FM only; and 8527.29.8000, Radiobroadcast receivers not capable of operating without an external source of power, of a kind used in motor vehicles other than those in 8527.29.000, accessed March 11, 2024.
Note: Dashed line used for imports of HTS 8527.29.4000, and dotted line used for imports of HTS 8527.29.8000).

The growth in U.S. demand and imports, however, has been accompanied by a drastic growth in trade concentration and reliance (figure 10). Over the last decade the country-level Import HHI value for HTS 8527.29.4000 has risen from 4,387 in 2012 to 9,771 in 2022, indicating a huge increase in concentration of U.S. imports. That same excessive concentration can be seen when scaling to the regional level, where the Regional HHI value for HTS 8527.29.400 rose from 4,827 in 2012 to 9,772 in 2022, further buttressing any claims of excessive concentration in U.S. imports of HTS 8527.29.4000.

U.S. imports of HTS 8527.29.8000 show similar patterns. Between 2012 and 2022, the Import HHI value on a country-level increased from 4,630 to 6,842, while the Regional HHI value rose from 4,992 to 6,855. As with HTS 8527.29.4000, a similar growth in excessive concentration and reliance of U.S. imports on one country and region is seen for HTS 8527.29.8000.

Figure 10: HHI for certain radios, 2012–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS statistical reporting numbers 8527.29.4000 and 8527.29.8000, accessed March 11, 2024; S&P Global Market Intelligence, "HS subheading 8527.29," accessed May 5, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

A large part of this concentration has been driven by both a redirection to and growth in trade with Mexico. In 2012, although Mexico was the largest source of U.S. imports for HTS 8527.29.4000 and HTS 8527.29.8000, import shares stood at 55.8 percent and 64.9 percent, respectively. Since then, the volume of trade has increased sevenfold in both products, and so has Mexico's share of it. As of 2022 Mexico supplies 98.8 percent and 82.0 percent of U.S. imports for HTS 8527.29.4000 and HTS 8527.29.8000. Other countries' shares have been diluted with the growth in volume: China commanded 35.5 percent and 18.6 percent share of U.S. imports of the two products in 2012, but by 2022 its shares had fallen to 0.3 percent and 5.7 percent. Furthermore, as of 2022, Mexico stood as the top exporter of said goods at the HS6 level, with an Export HHI value of 3,338. This not only shows a concentration and reliance of U.S. and global supply chains on Mexico for HTS 8527.29.4000 and HTS 8527.29.8000, but also indicates the potential lack of a viable alternative source for the United States. Mexico is also reliant on the United States, which has been the only destination for such exports since 2019.[55]

Tungsten halogen lamps for motor vehicles (HTS 8539.21.2040)

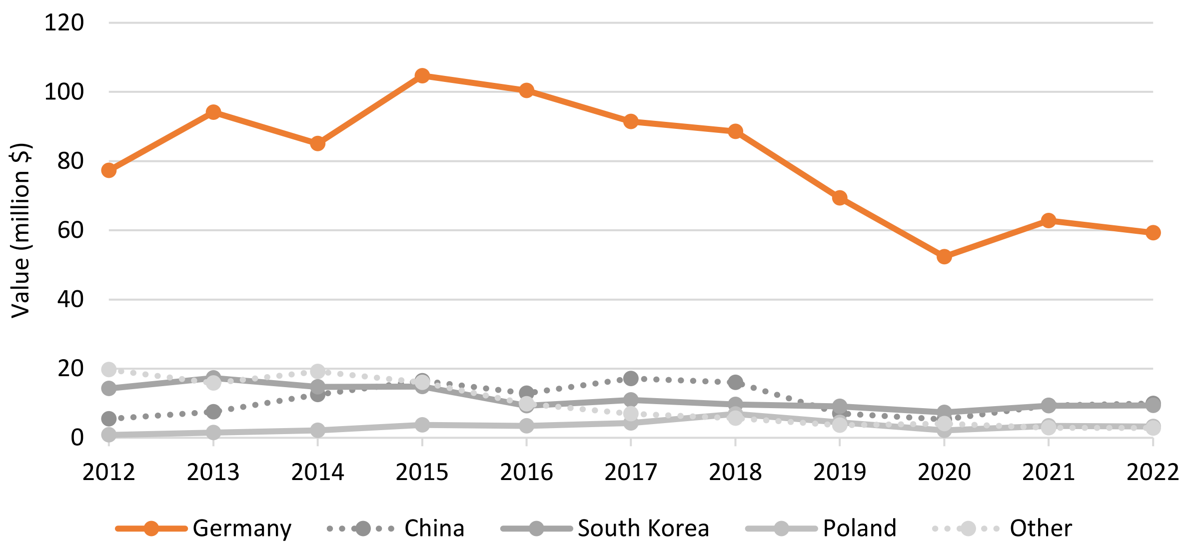
Tungsten halogen lamps are relatively high-end headlamps for motor vehicles that emit a bright white light. U.S. imports of tungsten halogen lamps for motor vehicles have declined since 2012, driven mostly by imports from Germany, the dominant supplier, which declined from nearly $80 million in 2012 to roughly $60 million in 2022, but also from other sources (figure 11). The decline in U.S. halogen lamp

[55] S&P Global, Global Trade Atlas, accessed July 30, 2025.

imports was likely driven by increased installation of LED headlamps, particularly since 2019.[56] LED headlamps could likely be a substitute if there was a supply disruption.

Figure 11: U.S. imports of tungsten halogen lamps for motor vehicles, 2012–22

In millions of dollars.



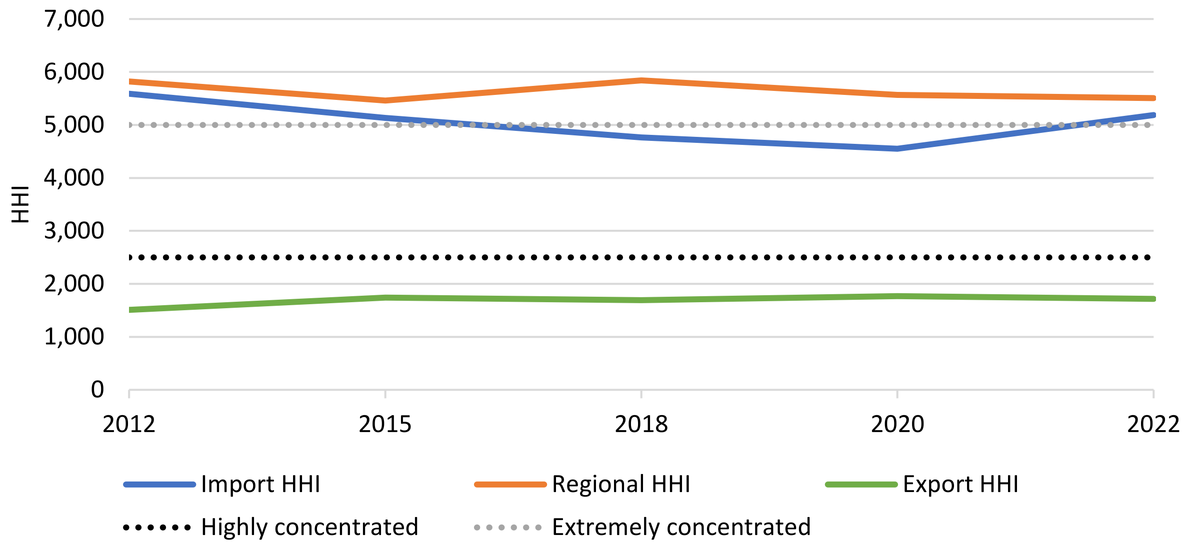
Source: USITC DataWeb/Census, HTS statistical reporting number 8539.21.2040, Tungsten halogen lamps designed for a voltage not exceeding 100V for vehicles of subheading 8701.21, 8701.22, 8701.23, 8701.24 or 8701.29 or heading 8702, 8703, 8704, 8705 or 8711, accessed April 24, 2024.

Import HHI remained highly concentrated due to total imports, and imports from the top source, both declining (figure 12). Regional HHI remained above 5,000 throughout the period as well. Export HHI remained below 2,000, potentially implying that multiple countries could potentially fulfill U.S. demand for tungsten halogen lamps despite current reliance on Germany.

[56] Market Research Future, “Automotive LED Headlamps Market Size, Growth, Trends, Report 2034,” January 2025.

Figure 12: HHI for tungsten halogen lamps, 2012–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS 8539.21.2040, accessed March 11, 2024; S&P Global Market Intelligence, "HS 8539.12," accessed May 5, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

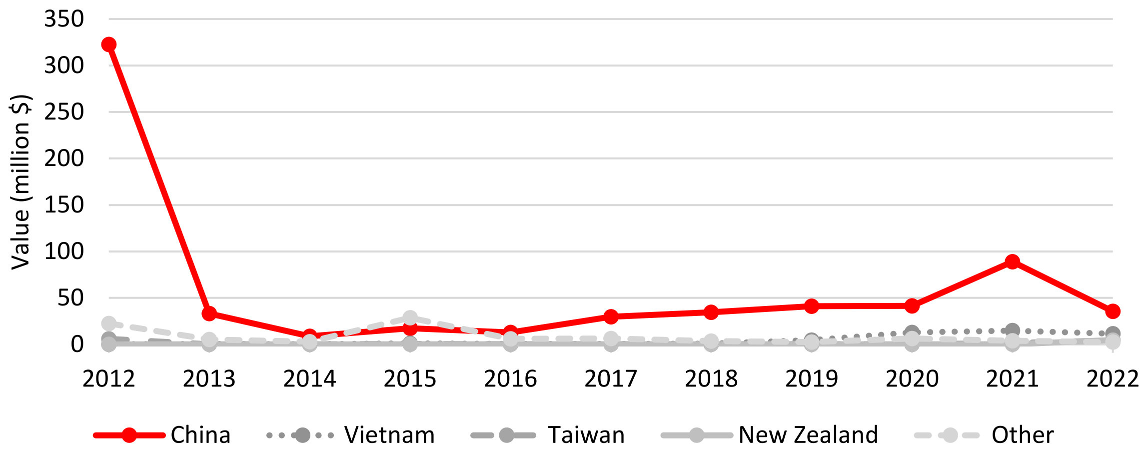
Radio telephones designed for installation in motor vehicles (HTS 8517.14.0020 and 8517.12.0020)[57]

U.S. imports of radio telephones designed for installation in motor vehicles, commonly called "data communication modules or DCMs," were concentrated with an Import HHI of over 4,000 in 2022. Most imports came from China, which made up 60 percent ($35.7 million) in 2022 (figure 13). DCMs enable "connected car" capabilities such as in-vehicle wi-fi, cellular services, and other connectivity options.

[57] In 2022 the WCO separated DCMs from smartphones. HS 8517.12 (Telephones for cellular networks or other wireless networks) was split into HS 8517.13 (smartphones for wireless networks) and HS 8517.14. HS 8517.12 had a statistical reporting number (HTS 8517.12.0020) that appears to be a 1:1 match with HTS 8517.14.0020. That number is used for imports from 2012 to 2021. WCO, "Correlation Tables HS 2017 – 2022," accessed May 8, 2024.

Figure 13: U.S. imports of DCMs, 2012–22

In millions of dollars.



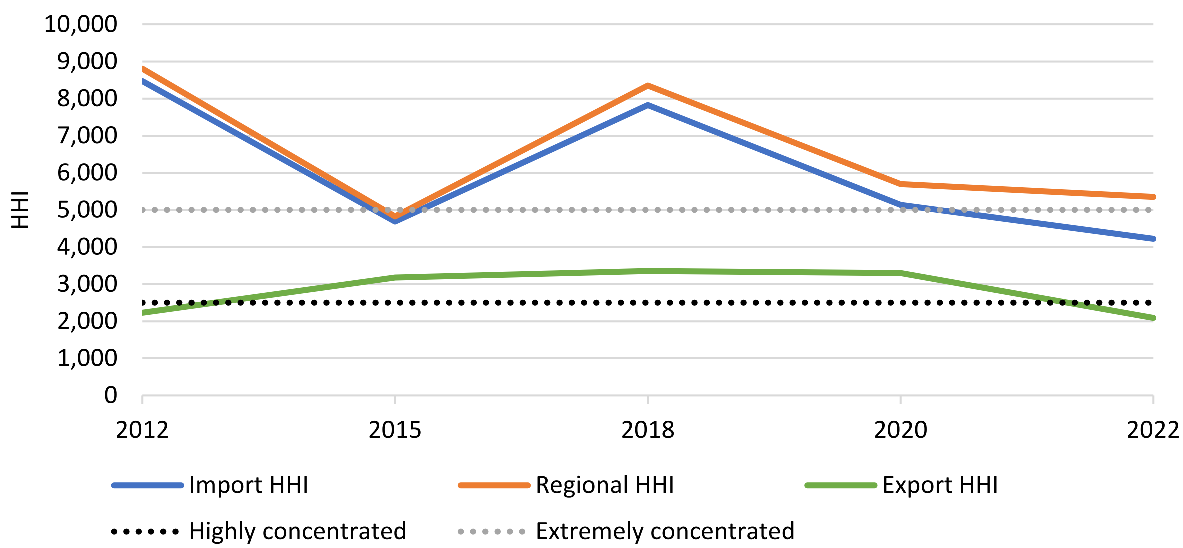
Source: USITC DataWeb/Census, HTS statistical reporting numbers 8517.14.0020 and 8517.12.0020, Radio telephones designed for installation in motor vehicles, accessed March 19, 2024.

Concentration was lower for all three measures of HHI in 2022, possibly indicating reduced vulnerability of this portion of the supply chain (figure 14). Alternatively, the lower number may also be because the WCO changed the way it classifies products with cellular connections in 2022. HS 2022 revisions split the cellular connection subheading (HS 8517.12) into two subheadings, one for smartphones (HS 8517.13), and a separate one for other cellular connections (HS 8517.14).[58]

[58] WCO, "Correlation Tables HS 2017 – 2022," accessed May 8, 2024.

Figure 14: HHI for DCMs, by year, 2012–22

In index value.



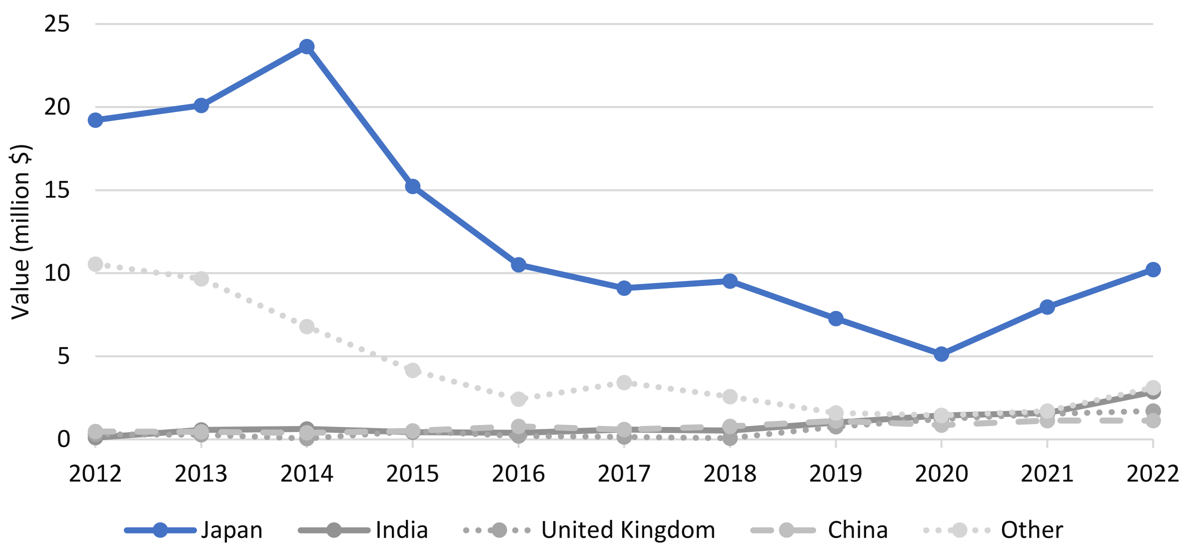
Source: Calculated based on import data from USITC DataWeb/Census, HTS statistical reporting numbers for radio telephones designed for installation in motor vehicles, 8517.14.0020 and 8517.12.0020, accessed March 11, 2024; S&P Global Market Intelligence, "HS subheading 8517.12 and 8517.14," accessed May 5, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

Friction material, not brake linings, for motor vehicles (HTS 6813.89.0050)

U.S. imports of friction material other than brake linings were highly concentrated in 2022, with more than half coming from Japan ($10.3 million or 53.7 percent). Such friction material is used in clutch discs for transmissions, but also has other uses. Japan was the leading source of imports during each year from 2018 to 2022 (figure 15). However, the global leader in exports of the subheading (which includes friction material for civil aircraft) is the United States, which could mean that the United States does not heavily rely on such materials from Japan.

Figure 15: U.S. imports of friction materials other than brake linings, other, 2012–22

In millions of dollars

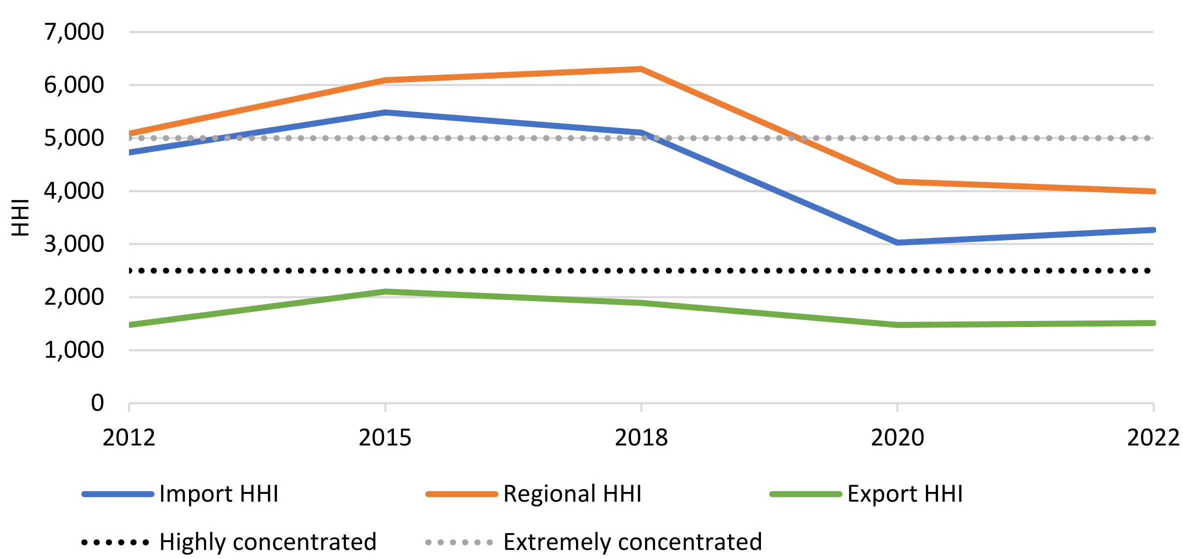


Source: USITC DataWeb/Census, HTS statistical reporting number 6813.89.0050, other friction materials for brakes or clutches not containing asbestos or for civil aircraft use, accessed March 20, 2024.

Both the Import and Regional HHIs for friction materials declined from 2012 to 2022, reflecting a decrease in imports from Japan and increased imports from India. However, neither the Import HHI nor Regional HHI ever came close to dropping below 2,500, the minimum level for the concentrated category (figure 16).

Figure 16: HHI for friction material, 2012–22

In index value.



Source: Calculated based on import data from USITC DataWeb/Census, HTS statistical reporting number 6813.89.0050, accessed March 11, 2024; and S&P Global Market Intelligence, "HS subheading 6813.89, friction materials and articles thereof," accessed May 5, 2024.
Note: HHI values >2,500 are highly concentrated, HHI values >5,000 are extremely concentrated.

Conclusion

Research on supply chain resilience is an established and growing field that experienced renewed interest after unprecedented disruptions to global trade during the COVID-19 pandemic. This paper contributes to the existing literature on supply chain resilience by applying a simple and accessible empirical method to identify potential vulnerabilities in the U.S. automotive supply chain at a national level, rather than from a purely business perspective. It further adds qualitative analysis to help contextualize potential vulnerabilities. Importantly, this methodology can be replicated and applied to any industry for which detailed trade data is available and intermediate inputs are readily identifiable in the Harmonized System.

Eight products were identified as potentially vulnerable automotive parts for which U.S. imports were highly concentrated and global exports were constrained. Once potential weak links were identified, qualitative research provided further detail. For example, in the case of lithium-ion batteries, Export HHI was the highest and Import HHI was the third highest of all eight selected products, showing that global trade as well as U.S. imports specifically are concentrated in China. That said, further research of the battery supply chain suggests that previously announced investments in the EU and United States will significantly reduce dependence on China. Furthermore, over 1,000 gigawatt hours per year of U.S. production capacity of lithium-ion batteries is expected to come online by 2028, which will satisfy 100 percent of projected demand.[59] Qualitative research revealed that several of the other products identified were either not integral parts of the vehicle (jacks), readily substitutable (headlamps and radios), or possibly not import reliant (friction materials).

One product, catalytic converters, appeared to be integral to the vehicle without a ready substitute or domestic supply. These parts are likely vulnerable to disruption. Geographic proximity to the primary source (Mexico) reduces but does not eliminate the risk.

Although this paper provides a simple approach to identifying and understanding where vulnerabilities exist among U.S. imports of inputs on upstream supply chains, there are some weaknesses to this methodology. While HHI may be a useful tool for identifying potentially vulnerable supply chains, it is not authoritative on its own, with the potential to identify products within supply chains as vulnerable that may not be or vice versa. These false positives (or negatives) can happen for a variety of reasons:

1. **Variation in the aggregation of statistical codes-** some statistical codes aggregate several products together, potentially obscuring or amplifying their apparent vulnerability. Other codes separate products into categories that are not meaningful for the supply chain, which can create the false impression of overreliance on a specific source that may not be true for the underlying products.
2. **Variation in the grouping of trade partners-** as discussed in the data section, using data with the EU as a single market instead of using data with individual EU countries would have significantly increased the number of potentially vulnerable parts to analyze. Depending on the type of disruption one is concerned about or the distribution of the supply chain, one grouping of trade partners may make more sense than another.

[59] Environmental Defense Fund, *EDF Analysis on US Battery Capacity*, December 2023; Granholm, *National Blueprint for Lithium Batteries 2021-2030*.

3. **Lack of knowledge of substitutes-** HHI calculations do not take into account the availability of substitute products. For example, the radios identified as potentially vulnerable by HHI analysis have substitutes. Vehicle manufacturers could use other (less vulnerable) radio types as replacements with minimal disruption.
4. **Lack of information on the ability for producers to scale up production-** some products can be produced on existing supply chains with minimal modification. For example, a producer of one kind of stamped product may be able to pivot to a different stamped product relatively quickly. Because those products may be classified under different statistical codes, this HHI methodology assesses them as distinct inputs and would not incorporate that information into the HHI value for either statistical code. This lack of information could lead to misclassification of one code or the other as vulnerable when it is not.[60]

While other indexes account for many more factors, they also have significant data and calculation requirements. This relatively simple metric is a good starting point, and one that can be used to narrow down where qualitative analysis or application of a data-intensive metric or index might be useful.

[60] Robustness tests based on aggregation of HS codes were not performed, because the authors believe that without product-level qualitative analysis it is difficult to map HS statistical codes, tariff lines, and subheadings to production capacity or the ability of producers to change product offerings. Sometimes products are aggregated in the same tariff line according to the USHTS that could not be made in the same plant at all, sometimes the same item could be made on statistical codes that fall across several tariff lines (HS8s).

Appendix A Automotive Parts Data

As discussed in the methodology section above, the global export data at the HS6 statistical reporting level used to calculate the Export HHI values presented two options: export data with the EU member states as 27 individual reporters, or export data with the EU as a single trading bloc. The latter excludes any internal trading among EU members. Export HHI values were calculated for both datasets.

Table 2 in the main text highlights what eight automotive parts are identified as vulnerable if using an Export HHI threshold of 1,500 and treating the EU countries as individual reporters. Each of these eight automotive parts were discussed in further detail above. However, table A.1 below shows the additional 54 automotive parts identified as vulnerable if that same 1,500 threshold is used for Export HHI, but the EU is treated as a single trading entity. All 54 products also fulfill the criteria established in steps 1-3.

Table A.1: Potentially vulnerable HTS10 statistical reporting numbers in the U.S. automotive supply chain using global export data with EU treated as a single entity, based on 2022 import/export data
HHI in index value; U.S. imports in million dollars.

HTS10	Product Description	U.S. Imports ($ million)	Export HHI (EU)	Export HHI (individual)	Difference in Export HHI values
3819.00.0010	Hydraulic brake fluids	28	2072	1216	856
3819.00.0090	Other fluids for hydraulic transmissions	21	2072	1216	856
3820.00.0000	Antifreeze	44	2395	1033	1362
4009.32.0020	Brake hoses for motor vehicles	101	1680	930	750
4011.20.1025	Radial off-highway tires for rims of greater than 40.6cm	21	1968	1288	680
4011.20.5020	Non-radial tires for buses or trucks other than light trucks	17	1968	1288	680
7007.11.0010	Toughened safety glass for motor vehicles	110	2039	754	1285
7007.21.1110	Windshields for motor vehicles	148	2051	819	1232
7007.21.5100	Laminated safety glass other than windshields	140	2051	819	1232
7318.16.0015	non-locking chrome plated lugnuts	27	1691	1236	455
7318.16.0045	Other lugnuts	65	1691	1236	455
7320.10.3000	Leafsprings for motor vehicle suspensions on vehicles of less than 4 tons	196	1556	979	577
7320.10.6015	Leaf springs with a thickness of 1.6mm or more suitable for motor vehicle suspension of vehicles greater than 4 tons	331	1556	979	577
7320.10.6060	Leaf springs other than those with a thickness of 1.6mm or more suitable for motor vehicle suspension of vehicles greater than 4 tons	48	1556	979	577
8407.34.4400	Used or rebuilt spark-ignition engines for motor vehicles of greater than 2000ccs	161	1621	881	740
8407.34.4800	Spark-ignition engines for motor vehicles of greater than 2000ccs other than those used or rebuilt	5,750	1621	881	740

HTS10	Product Description	U.S. Imports ($ million)	Export HHI (EU)	Export HHI (individual)	Difference in Export HHI values
8408.20.2000	Compression-ignition engines for motor vehicles	1,823	2140	1027	1113
8414.80.0500	Turbochargers and superchargers	1,352	1731	851	880
8415.20.0000	Air conditioners for motor vehicles	304	1721	913	808
8415.90.8045	Parts of automotive air conditioners	1,546	2196	1390	807
8482.10.1040	Ball bearings with an integral shaft, with a diameter of not over 30mm	12	1713	1059	654
8501.32.4500	Electric motors of between 750w and 75kw for powering motor vehicles	15	1907	1257	650
8507.90.8000	Lithium-ion battery parts	4,146	1960	1439	522
8511.10.0000	Spark plugs	578	2064	1460	604
8511.20.0000	Ignition magnetos	23	2255	1354	901
8511.30.0040	Distributors	17	1851	1332	519
8511.50.0000	Other generators	1,295	1523	903	620
8511.90.2000	Parts of voltage and voltage-current regulators with cut-out relays for 6, 12 or 24v systems	16	1668	1279	388
8511.90.6040	Parts of ignition or starting equipment not elsewhere specified	323	1668	1279	388
8512.30.0030	Radar detectors of a kind used in motor vehicles	43	1909	1326	583
8512.40.4000	Windshield wipers	116	1710	979	730
8525.60.1010	Citizens Band (CB) transceivers	30	1510	984	526
8531.80.9031	Horns	11	2153	1473	680
8707.90.5020	Bodies for non-agricultural tractors	13	1611	936	675
8707.90.5040	Bodies for buses	31	1611	936	675
8707.90.5060	Bodies for vehicles for transport of goods	477	1611	936	675
8707.90.5080	Bodies for vehicles of HS 8705	37	1611	936	675
8708.21.0000	Safety seat-belts	353	1878	977	901
8708.30.1090	Parts of brakes other than mounted brake linings for tractors for agricultural use	46	1724	1001	724
8708.30.5020	Brake drums for vehicles other than agricultural vehicles	333	1724	1001	724
8708.30.5030	Brake rotors for vehicles other than agricultural vehicles	2,074	1724	1001	724
8708.30.5090	Other brake parts for vehicles other than agricultural vehicles	3,541	1724	1001	724
8708.40.1110	Gear boxes for passenger vehicles	5,178	1856	1303	553
8708.40.1150	Other gear boxes for motor vehicles	1,612	1856	1303	553
8708.70.4530	Road wheels for trucks and buses	580	2104	1244	860
8708.70.6030	Wheel rims for trucks and buses	217	2104	1244	860
8708.70.6045	Wheel covers and hubcaps for trucks and buses	67	2104	1244	860
8716.90.5010	Axles and parts thereof for trailers and semi-trailers	228	2318	1122	1196

HTS10	Product Description	U.S. Imports ($ million)	Export HHI (EU)	Export HHI (individual)	Difference in Export HHI values
8716.90.5056	Wheels with tires for off highway use for trailers and semi-trailers	36	2318	1122	1196
9029.20.4080	Other speedometers and tachometers	1,372	1707	1021	686
9401.20.0000	Seats of a kind used for motor vehicles	315	1533	846	686
9401.99.1010	Parts of leather for seats for motor vehicles cut to shape	1,078	1810	894	915
9401.99.1020	Parts of textile material for seats for motor vehicles cut to shape	861	1810	894	915
9401.99.1085	Other parts for seats for motor vehicles	5,727	1810	894	915

Sources: U.S. Department of Commerce Automotive parts list. HHI calculated based on data from USITC, DataWeb/Census (March 11, 2024); S&P Global, Global Trade Atlas, (March 11, 2024).

Bibliography

Alicke, Knut, Edward Barriball, Tacy Foster, Julien Mauhourat, and Vera Trautwein. "Supply Chain Disruption and Resilience." August 26, 2022. https://www.mckinsey.com/capabilities/operations/our-insights/taking-the-pulse-of-shifting-supply-chains#/.

Benigno, Gianluca, Julian Di Giovanni, Jan J. Groen, and Adam I Noble. "The GSCPI: A New Barometer of Global Supply Chain Pressures." *Federal Reserve Bank of New York* no. No. 1017 (May 2022). https://doi.org/10.2139/ssrn.4114973.

Bhutada, Govind. "Visualizing China's Dominance in Battery Manufacturing (2022-2027P)." Visual Capitalist, January 19, 2023. https://www.visualcapitalist.com/chinas-dominance-in-battery-manufacturing/.

Bohr, Peter. "Why More Cars Have a Tire Inflator Kit and What to Do about It." April 15, 2022. https://www.ace.aaa.com/publications/auto/drive-smart/.

Coffin, David, Dixie Downing, Jeff Horowitz, and Greg LaRocca. *The Roadblocks of the COVID-19 Pandemic in the U.S. Automotive Industry*. June 2022. https://www.usitc.gov/publications/332/working_papers/final_the_roadblocks_of_the_covid-19_pandemic_in_the_automotive_industry.pdf.

Compound Semiconductor. "Chips per Car to Rise to over a Thousand - News." Compound Semiconductor, December 5, 2022. https://compoundsemiconductor.net/article-gen/115795.

Craighead, Christopher, Jennifer Blackhurst, Manus Rungtusanatham, and Rob Handfield. "The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities." *Decision Sciences* 38, no. 1 (March 2007): 131–56. https://doi.org/10.1111/j.1540-5915.2007.00151.x.

Crosnier, Stéphane, and Maria Rey-Marston. "How Supply Chain Visibility Delivers Resilience." 2022. https://www.accenture.com/us-en/insights/consulting/visibility-delivers-supply-chain-resilience.

Environmental Defense Fund. *EDF Analysis on US Battery Capacity*. December 2023. https://www.edf.org/sites/default/files/2023-12/EDF%20Analysis%20on%20US%20Battery%20Capacity%2012.13.23%20final%20v3.pdf.

Federal Reserve Bank of New York. "Global Supply Chain Pressure Index." Accessed May 20, 2024. https://www.newyorkfed.org/research/policy/gscpi#/interactive.

Fiksel, Joseph. "Sustainability and Resilience: Toward a Systems Approach." *Sustainability: Science, Practice and Policy* 2, no. 2 (October 2006): 14–21. https://doi.org/10.1080/15487733.2006.11907980.

GitHub. "ISO-3166 Country and Dependent Territories Lists with UN Regional Codes." December 8, 2020. https://github.com/lukes/ISO-3166-Countries-with-Regional-Codes/tree/master?tab=readme-ov-file#readme.

Goodman, Samuel M. "A Method of Estimating Global Supply Chain Risk and Predicting the Impacts of Regional Disruptions." *U.S. International Trade Commission Office of Industries Working Paper Series* no. ICA-095 (January 2023): 1–10. https://www.usitc.gov/publications/332/working_papers/ica_095-_trade_concentration_paper_final.pdf.

Govshteyn, Misha. "Navigating the Great Supply Chain Reset." SupplyChainBrain, October 12, 2023. https://www.supplychainbrain.com/blogs/1-think-tank/post/38151-navigating-the-great-supply-chain-reset.

Granholm, Jennifer M. *National Blueprint for Lithium Batteries 2021-2030*. https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf.

Hosseini, Seyedmohsen, Dmitry Ivanov, and Jennifer Blackhurst. "Conceptualization and Measurement of Supply Chain Resilience in an Open-System Context." *IEEE Transactions on Engineering Management* 69, no. 6 (December 2022): 3111–26. https://doi.org/10.1109/TEM.2020.3026465.

International Energy Agency (IEA). "Global Supply Chains of EV Batteries – Analysis." IEA, July 2022. https://www.iea.org/reports/global-supply-chains-of-ev-batteries.

Klier, Thomas H., and James M. Rubenstein. "The Emerging Geography of Electric Vehicle Production in North America: Revolution or Evolution?" *Economic Perspectives* 4 (July 2024). https://doi.org/10.21033/ep-2024-4.

Lemmers, Oscar, Khee Fung Wong, Tom Notten, Leen Prenen, and Dennis Dahlmans. Which products are traded in your supply chain and how do they score on risk indicators? Statistics Netherlands; Dutch Ministry of Economic Affairs and Climate Policy. Accessed December 24, 2024. https://www.cbs.nl/-/media/_pdf/2024/11/240228_wereldcafe_lemmers.pdf.

Li, Ruiying, Qiang Dong, Chong Jin, and Rui Kang. "A New Resilience Measure for Supply Chain Networks." *Sustainability* 9, no. 1 (January 2017): 144. https://doi.org/10.3390/su9010144.

Market Research Future. "Automotive Led Headlamps Market Size, Growth, Trends, Report 2034." January 2025. https://www.marketresearchfuture.com/reports/automotive-led-headlamps-market-23725.

Munoz, Albert, and Michelle Dunbar. "On the Quantification of Operational Supply Chain Resilience." *International Journal of Production Research* 53, no. 22 (November 17, 2015): 6736–51. https://doi.org/10.1080/00207543.2015.1057296.

Pettit, Timothy, Joseph Fiksel, and Keely Croxton. "Ensuring Supply Chain Resilience: Development of a Conceptual Framework." *Journal of Business Logistics* 31 (March 1, 2010): 1–21. https://doi.org/10.1002/j.2158-1592.2010.tb00125.x.

Ponis, Stavros T., and Epaminondas Koronis. "Supply Chain Resilience: Definition Of Concept And Its Formative Elements." *Journal of Applied Business Research (JABR)* 28, no. 5 (August 21, 2012): 921–30. https://doi.org/10.19030/jabr.v28i5.7234.

Scaff, Renato. “Create the New Global Supply Chain.” September 22, 2022. https://www.accenture.com/us-en/blogs/business-functions-blog/global-supply-chain-reinventing-itself.

Seetharaman, Deepa. “Automakers Face Paint Shortage after Japan Quake.” *Reuters*, March 26, 2011. https://www.reuters.com/article/idUSN25285934/.

United Nations Statistics Division (UNSD). “Standard Country or Area Codes for Statistical Use (M49) Methodology.” Accessed May 29, 2024. https://unstats.un.org/unsd/methodology/m49/overview.

Universal Technical Institute (UTI). “What Is a Catalytic Converter and What Does It Do?” UTI Corporate, January 6, 2021. https://www.uti.edu/blog/automotive/catalytic-converter.

U.S. Department of Commerce. “Automotive Parts Tariff Codes.” 2023. https://www.trade.gov/automotive-parts-tariff-codes.

U.S. Department of Labor, Bureau of Labor Statistics. “Automotive Industry: Employment, Earnings, and Hours.” Accessed December 1, 2022. https://www.bls.gov/iag/tgs/iagauto.htm.

USITC. *U.S.-Mexico-Canada Trade Agreement: Likely Impact on the U.S. Economy and on Specific Industry Sectors*. April 2019. https://www.usitc.gov/publications/332/pub4889.pdf.

World Customs Organization (WCO). “Correlation Tables HS 2017 – 2022.” Accessed May 8, 2024. https://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools/hs-nomenclature-2022-edition/correlation-tables-hs-2017-2022.aspx.

Yogaananthan. *Building Resilient Supply Chains: Three Strategies*. S. Rajaratnam School of International Studies, 2020. https://www.jstor.org/stable/resrep25424.6.