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Prepared for:
Department of Homeland Security

Is Natural Rubber the Next Critical Material to Challenge the U.S. Economy?

An Evaluation of Threats to Supply

June 24, 2024

Version 1.0
Contract ID: 70RSAT20D00000001
Task Order: 70RWMD23FRP000003.

Homeland Security

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Case Number 24-2127 / DHS reference number 70RWMD23FR-003-02

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Abstract

Natural rubber is a key ingredient in over 50,000 products in a large number of industries. These uses include tires for aviation and automobiles and critical medical supplies, such as catheters and gloves. A sudden decline in rubber inputs would impose significant costs on both the economy and national security.

Presently, virtually all natural rubber comes from rubber trees (*Hevea brasiliensis*). The U.S. imports almost all its natural rubber from a few countries in Southeast Asia. Unfortunately, the supply of rubber responds slowly to increases in demand. It takes about seven to ten years for a newly planted rubber tree to produce latex.

In addition to steadily growing demand, supplies also face a number of specific threats, including disease, climate change, dependence on a small number of countries, and shipping lanes which are vulnerable to political disputes. Rubber markets are also heavily influenced by China, which is the largest importer of natural rubber. China has been expanding its physical and economic presence in nations that produce natural rubber. It is also the sole source for many of the products needed to make synthetic rubber.

To address this vulnerability, the U.S. should consider creating a national stockpile of natural rubber that could be drawn down in times of scarcity. It should also significantly increase federal research into alternative sources of rubber, including synthetic rubber. Finally, it should work with producing nations to increase yields and reduce environmental concerns.

Key Words

1. Natural Rubber
2. Synthetic Rubber
3. Climate Change
4. South American Leaf Blight
5. Structural Gravity Model

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Record of Changes

No.	Date	Reference	A=Add M=Modify D=Delete	Description of Change
1	6/14/2024			Initial draft
2	6/24/2024		A	Added new DHS logo and context
3	10/30/2024		M	Approved for Public Release
4	12/12/2024		A	Added Figure 6 and Figure 7

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1 Executive Summary

This paper discusses the large costs that a significant decline in the supply of natural rubber would have on the United States (U.S.) economy and national security. Natural rubber (*Hevea brasiliensis*) from rubber trees is used in tens of thousands of products across the economy. Although substitutes exist, in many cases they are inferior to natural rubber.[1] In addition, some of these products are critical to daily life, including tires in the automative and aviation sectors and a range of vital medical products needed to prevent the spread of disease and save lives.

Unfortunately, it is very possible that the world could experience significant shortages of supply in the near future. To begin with, continued economic growth in the U.S. and abroad, and the movement toward electric vehicles, which are almost 20 percent heavier than traditional models, will likely lead to a rapid increase in demand.[2] Yet it is difficult to quickly increase the supply of natural rubber. It takes seven to ten years for a newly planted tree to begin producing latex. Low rubber prices and pressure to halt deforestation provide little incentive to plant more trees.

In addition to the normal battle between supply and demand, several more specific threats exist. One is that rubber trees are susceptible to a number of diseases, most significantly South American Leaf Blight.[3] In addition to significantly reducing current production, these diseases can permanently destroy a region's future ability to grow rubber. Second, global warming is expected to shift the ideal regions for growing natural rubber. Rubber trees grow best in regions where the average temperature is between 25 and 28 degrees Celsius and rainfall is around 1500 millimeters per year. Absent significant reductions in greenhouse gas emissions, temperature rise is expected to result in warming that exceeds these constraints. Finally, the current supply chains are very vulnerable. The vast majority of rubber is produced in a few Southeast Asian countries that ship most of their product through the South China Sea, which China is currently trying to exert control over. Any interruption in shipments would have major implication for the U.S.

China is currently much better positioned to respond to any decline in supply than the United States. The Chinese government has set up a global network of interconnected firms that have been investing in plantations and processing plants. In the event of a territorial conflict China could threaten U.S. rubber imports.

The U.S. should consider adopting policies to reduce the likelihood and cost of these threats. First it should reestablish and fund a significant reserve supply of natural rubber, similar to the petroleum reserve. Second, it should significantly increase spending on research and development. There are undoubtedly ways in which synthetic rubber could be used for more purposes. In addition, two other plants may prove to be good sources of latex. Finally, the U.S.

[1] "Natural vs. Synthetic Rubber," GMT Rubber website, https://www.gmtrubber.com/natural-vs-synthetic-rubber/.

[2] Bruce, Derek, "How Much Does an Electric Vehicle Weigh," EVIUSA website, January 1, 2023, https://evi-usa.com/how-much-does-an-electric-vehicle-weigh/#google_vignette.

[3] "Innovative New Technology Could Boost US Rubber Production," *SciTechDaily*, January 28, 2024, https://scitechdaily.com/innovative-new-technology-could-boost-us-rubber-production/.

needs to work with producing nations, especially those outside of Asia, to protect crops and increase yields.

2 Introduction

The Health, Food and Agriculture Resilience Directorate at the Office of Health Security, Department of Homeland Security focuses on mitigating high consequence threats to the food and agriculture sectors. Any serious threat to the natural rubber supply chain is a high consequence threat to national security for the reasons that this paper will outline. The Homeland Security Systems Engineering & Development Institute (HSSEDI) was asked to examine possible threats to the U.S. supply of natural rubber.

Rubber is valued for its durability and resistance to heat and chemicals and is used to manufacture tires, gaskets, and many other industrial products.[4] Natural rubber is integral to thousands of products in the healthcare space, but it is particularly important for things like fluid and breathing tubes, prosthetics, blood pressure cuffs, pacemaker leads, tourniquets, personal protective equipment and caps and seals. As a result of this dependence, in February 2021, the U.S. government had to invoke the Defense Production Act to increase production of rubber gloves in the U.S, thus demonstrating the vital importance of this particular rubber product to preserving national health.[5]

Vulcanized rubber can withstand the rigors, including heat, of hospital sterilization. It also can protect against bacterial growth and is therefore less likely be to an agent of local and mass disease spread. It was critical during the COVID-19 pandemic for that reason. In addition, natural rubber is important to the economic well-being of the United States and is a critical material relative to national and economic security, including our military defense.

For over 150 years, natural rubber (*Hevea brasiliensis*, otherwise known as rubber trees) has been an increasingly important input into a large number of products. Although different types of synthetic rubber exist, and some of them are superior to natural rubber for certain purposes, none of them can fully replace natural rubber in all its uses. None are good candidates for replacement in aircraft and heavy equipment tires, an integral part of any modern economy.

Over the past few years several trends have threatened the existing supply of natural rubber. These threats include exposure to South American Leaf Blight, which can destroy a region's ability to produce natural rubber in the future unless it's properly managed. Rubber trees are monoclonal plants and therefore are particularly susceptible to disease. Climate change is also shifting the optimal growing regions for natural rubber. Given the long lead time in establishing new sources of supply, (rubber trees take seven to ten years to fully mature and begin producing)

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[4] Liné, "Latex vs Rubber: Is it the Same Thing?" Eco World website, https://ecoworldonline.com/latex-vs-rubber-is-it-the-same-thing/.

[5] Hellman, Jessie, "Biden to use DPA to Boost Production of COVID-19 Tests, Gloves, Vaccine Supplies, *The Hill*, February 5, 2021, https://thehill.com/policy/healthcare/537538-biden-to-use-dpa-to-boost-production-of-covid-19-tests-gloves-vaccine/.

this transition may be accompanied by a significant shortfall in world production.[6] Past efforts to increase production have caused significant deforestation, leading to an international effort to restrict future growth.

Even outside of these threats, rapidly growing demand may cause a spike in prices. Prior to the COVID pandemic, world demand for natural rubber was increasing much faster than supply.[7] Although demand fell for the next few years, it has rebounded sharply as growing economic development increases the demand for tires and other products.

Finally, there are some signs that the Chinese government may be able to reduce U.S. imports of natural rubber. The U.S. imports almost all its natural rubber from Thailand and Indonesia, both of which have strong ties to the Chinese rubber industry and must ship their product out through sea lanes that China seeks to control. As a major producer of and the world's leading consumer of natural rubber, the Chinese government may be able to raise the price of U.S. imports. There is also evidence that Chinese companies have been buying plantations, shipping capacity, and processing plants abroad to build integrated rubber supply chains. While the purpose of this activity is not yet fully understood, it could allow China to threaten U.S. access to major suppliers of natural rubber.

While it is true that synthetic rubber can replace some uses of natural rubber, the Chinese currently produce many of the chemicals needed to produce it. Over 40 percent of all critical rubber chemicals are controlled through China's manufacturing dominance. Manufacturing of key chemicals such as benzothiazyl disulfide or dicumyl peroxide is only done in China. Even when chemicals are produced in Europe, in many cases the feedstocks are still sourced in China.[8] Considering these threats, it is prudent for the United States to develop a national strategy for responding to a sudden and severe shock to the availability of both natural rubber and its synthetic counterparts. Specifically, the U.S. should consider establishing a national reserve similar to those for oil and helium. The federal government should also make significant investments in research to develop new forms of rubber as well as substitutes and to source the chemicals needed to make them at home. In addition, the government needs to work with other nations to expand rubber exports and develop a better understanding of China's growing role in rubber markets.

[6] 27. Mooibroek, H. and Cornish, K., "Alternative Sources of Natural Rubber," *Applied Microbiology and Biotechnology*, vol. 53, (2000), https://cornishlab.cfaes.ohio-state.edu/sites/hcs-cornishlab/files/imce/Alternative%20sources%20of%20natural%20rubber.pdf.

[7] Cornish, Katrina, "Alternative Natural Rubber Crops: Why Should We Care?" *Technology and Innovation*, vol. 18, 2017, doi.org/10.21300/18.4.2017.245.

[8] Pustay Beaven, Erin, "Joe Walker: Dwindling Supply of U.S.-Made Rubber Chemicals a National Security Risk, *Rubber News*, May 1, 2024, https://www.rubbernews.com/news/low-supply-us-made-rubber-chemicals-could-be-national-security-risk; Walker, Joe, "Guest Column: Sounding the Alarm on Security of Rubber Chemicals Supply," *Rubber News*, April 18, 2023, https://www.rubbernews.com/opinion/joe-walker-us-needs-domestic-production-critical-rubber-chemicals.

3 The International Rubber Market

This section looks at the features, price, volume, and main suppliers and importers of natural rubber. Certain plants produce latex, a milky fluid known for its elasticity and flexibility. Latex in its liquid form is used to produce a range of products, including gloves, and ballons. Latex can be transformed into rubber by adding acid and allowing it to coagulate so that it can be rolled into sheets and dried. A chemical process known as vulcanization can further improve the properties of natural rubber, including making the rubber more flexible under a wider array of temperatures.

Figure 1 shows the global price of natural rubber since 1990. It is easy to see wild swings in the price from year to year. Although prices are significantly below peaks earlier this century, they still exhibit significant volatility. Moreover, these prices do not account for inflation. Real prices have been declining for about a decade. In this environment market participants face greater uncertainty, and market prices give little guidance to producers and consumers.

Figure 1: Global Price of Natural Rubber[9]

The goods marked for delivery in rubber futures contracts are not typically the same variety as the spot goods purchased by downstream users. This creates an opening for arbitrage. Widespread arbitrage has significantly impacted all aspects of the domestic natural rubber market including supply and demand, inventories, and price. Since 2017 supply and demand seem to have had little effect on the price of natural rubber. The constant decline in real prices has stimulated greater demand without giving producers an incentive to increase supply.[10]

[9] FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/PRUBBUSDM.

[10] "Stretching the Limits: How Arbitrage in China is Disrupting the Natural Rubber Supply Chain," GEP website, June 24, 2019, https://www.gep.com/blog/mind/stretching-the-limits-how-arbitrage-in-china-is-disrupting-the-natural-rubber-supply-chain.

Over 90 percent of the world's natural rubber supply is exported. Figure 2 shows the top seven producers of natural rubber in 2022. Thailand and Indonesia are currently responsible for 63 percent of all production. Currently *90 percent of natural rubber comes from rubber trees in Southeast Asia*. The strong concentration of production in a few countries raises the possibility of sudden declines in global supply. Given restrictions on new growing areas and long lead times in expanding production, any shortages could be long-lasting.

Figure 2: Leading Natural Rubber Producing Countries in 2022[11]

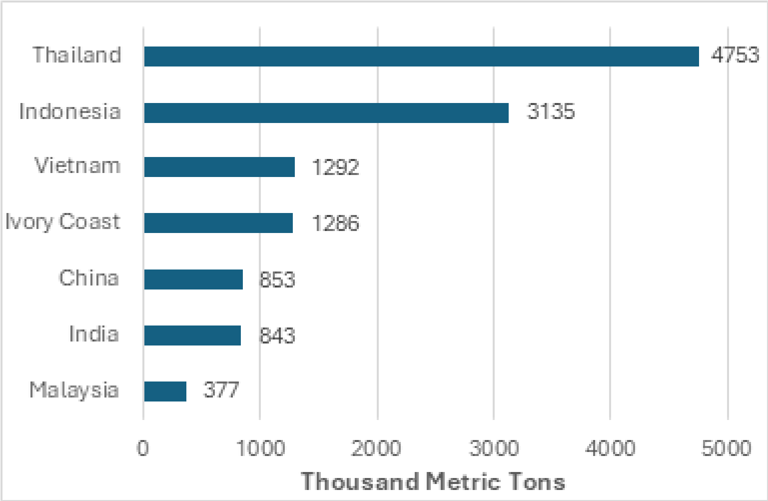
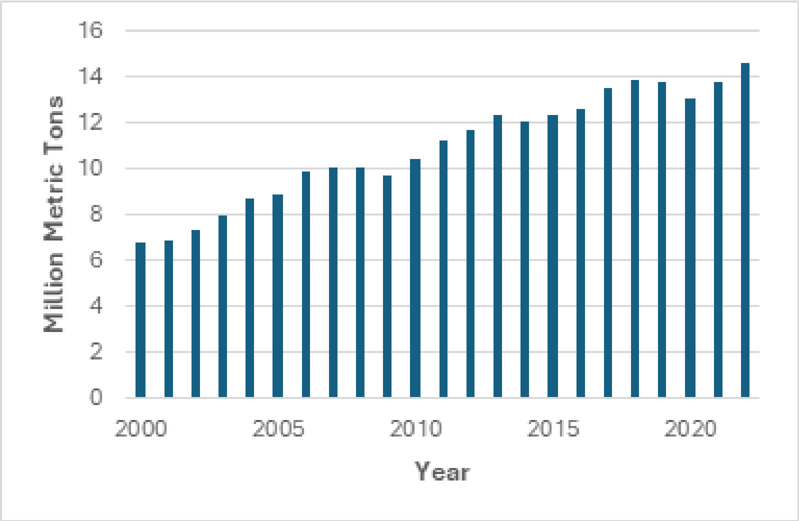


Figure 3 shows global production of natural rubber from 2000 to 2022. Although production increased significantly until 2017, it has leveled off since then.

Figure 3: Production of Natural Rubber Worldwide[12]



[11] Statista, https://www.statista.com/statistics/275397/caoutchouc-production-in-leading countries/.

[12] Statista, https://www.statista.com/statistics/275387/global-natural-rubber-production.

Figure 4 shows the top ten importers of natural rubber by value for 2022. The United States imported most of its natural rubber from Indonesia (50.6%) and Thailand (25.7%). China has become the dominant importer of natural rubber, using much of it to feed a growing domestic and international market in vehicle tires.

Figure 4: Top Importers of Natural Rubber in 2022[13]

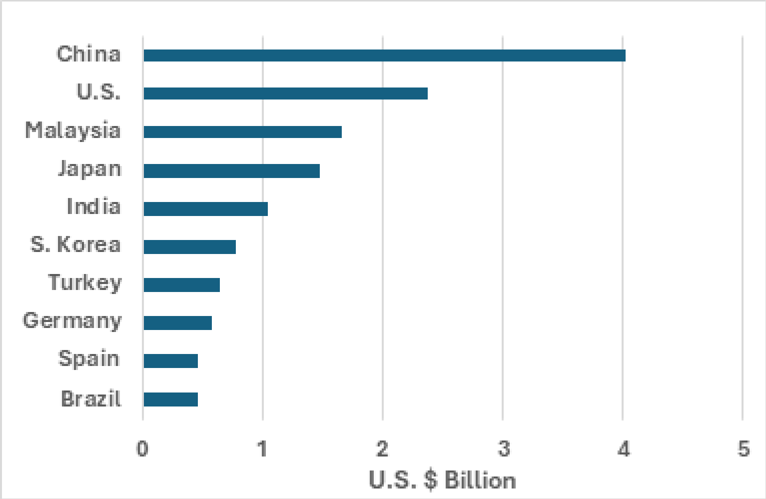
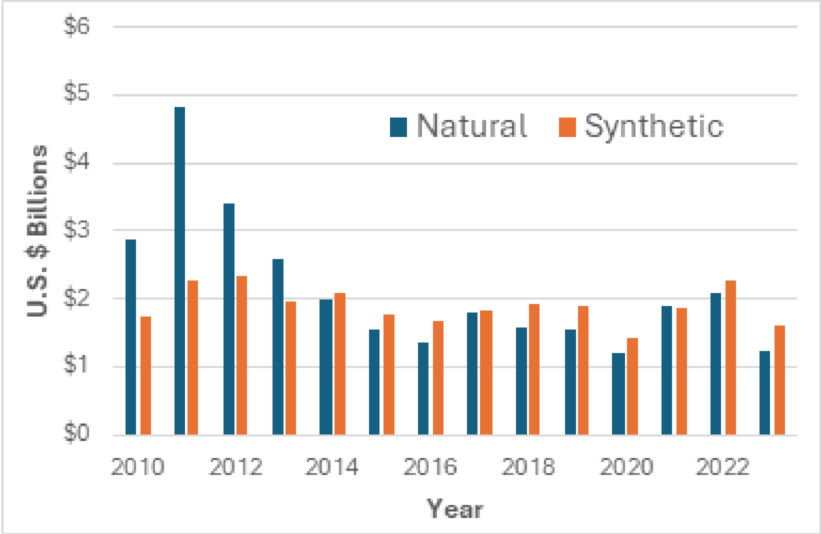


Figure 5 shows the total value of both natural rubber and synthetic rubber for the world since 2010. It is important to remember that synthetic rubber has better qualities for some products than natural rubber does. As a result, it will always be in demand. However, natural rubber is also strongly preferred for many uses, including important products such as tires, medical gloves, and sealants. It is particularly preferred for its heat resistance.

[13] Workman, Daniel, "Natural Rubber Imports by Country, https://www.worldstopexports.com/natural-rubber-imports-by-country/#:~:text=The%205%20biggest%20importers%20of%20natural%20rubber%20are,total%20worldwide%20purchases%20of%20globally%20imported%20natural%20rubber.

Figure 5: Value of Natural and Synthetic Rubber Imports to the U.S.[14]



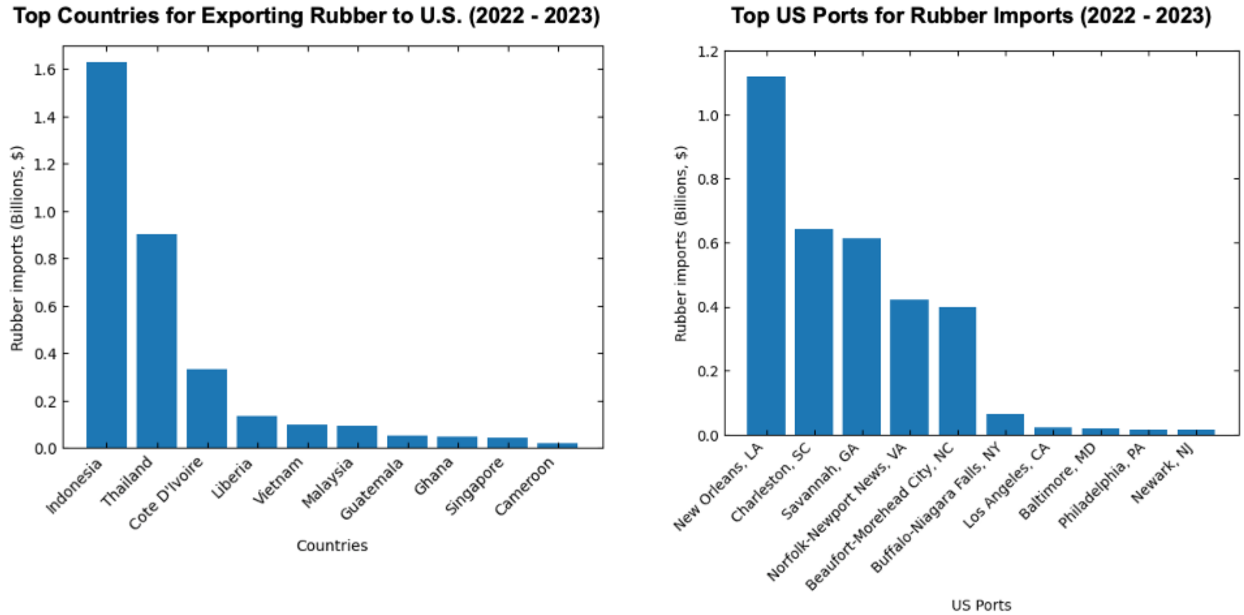
We can see that the values of natural and synthetic rubber are currently similar, due largely to a significant drop in the value of natural rubber since 2011. That in turn was caused by a fall in price rather than volume. Overall, 65 percent of rubber consumed worldwide is artificial, derived from fossil fuels, which creates its own problems. Synthetic rubber is cheaper and more hardwearing than natural rubber, but the latter disperses heat better and has better grip, which is why tires currently require a mix of both.[15]

Building on Figure 4 and Figure 5, Figure 6 shows which countries are exporting natural rubber to the US specifically. Three quarters of US natural rubber imports come from just two countries: Indonesia (48%) and Thailand (27%). Other countries in Africa (Cote D'Ivoire, Liberia, Ghana, and Cameroon), Southeast Asia (Vietnam, Malaysia, and Singapore), and Central America (Guatemala) round out the top ten exporters to the US. **Error! Reference source not found.** a lso shows the US ports that receive natural rubber from abroad. About one third of all natural rubber imports come through New Orleans, LA. Other ports that receive a large volume of natural rubber are Charleston, SC, Savannah, GA, Norfolk-Newport News, VA, and Beaufort-Morehead City, NC.

[14] International Trade Management Division, "USA Trade Online." United States Census Bureau, 2023, https://www.census.gov/foreign-trade/data/index.html.

[15] McGovan, Jack, "Dandelion Rubber for Sustainable Tires?" DW, March 10, 2021, https://www.dw.com/en/could-rubber-from-dandelions-make-tires-more-sustainable/a-56766389.

Figure 6: Countries exporting natural rubber to the US (left) and US ports that receive natural rubber imports (right).



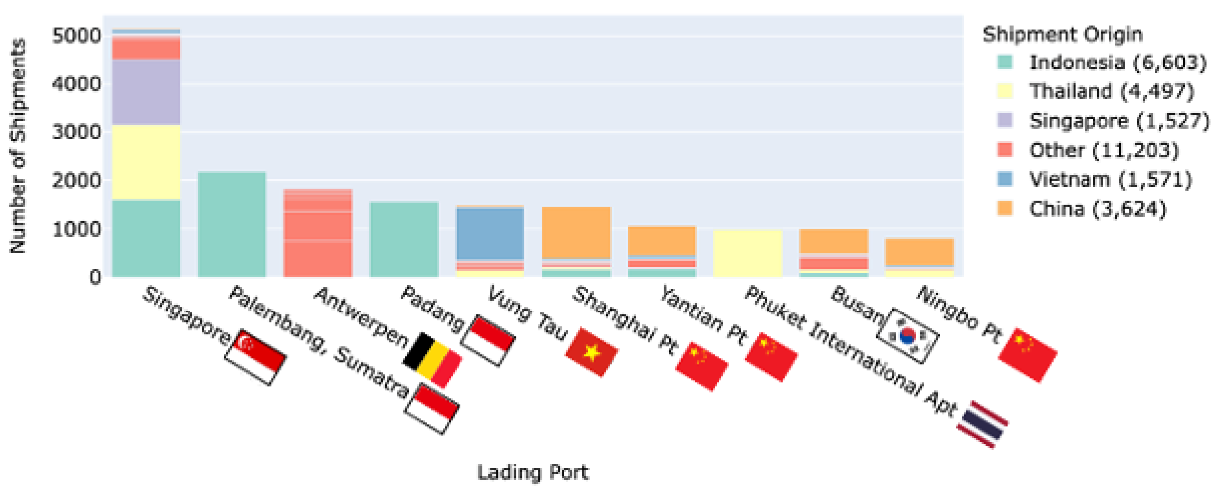
Combining the left and right panels of Figure 6, Figure 7 shows which exporting countries send natural rubber to which ports in the US. Indonesia primarily sends natural rubber to New Orleans, LA and Beauford-Morehead City, NC; Thailand primarily sends natural rubber to Charleston, SC and New Orleans, LA. Notably, Cote D'Ivoire primarily sends natural rubber to Savannah, GA, and Liberia primarily sends natural rubber to Norfolk-Newport News, VA.

Figure 7 starts to build out the overall structure of the natural rubber supply chain network that will be explored in more detail in the next section. However, it just shows the exporting country and the US port it arrives at; it does not show any natural rubber stops in between. Figure 8 shows the lading port for natural rubber shipments into the US (the lading port is the last stop of a shipment prior to coming to the US). Figure 8 shows the top ports of lading, colored by the origin country. Singapore is a major transshipment hub for natural rubber, handling shipments originating in Indonesia and Thailand on their way to the US. Antwerpen is also a major transshipment hub, handling shipments originating in Cote D'Ivoire, Ghana, and Liberia (colored red in Figure 8).

Figure 8 was built using data from Panjiva, a commercial dataset from S&P Global. It provides global trade data on commodity imports and exports across a variety of worldwide supply chains. Panjiva data is sourced through the bills of lading when goods are unloaded at destination ports, and is thus dependent on input from exporter, meaning the data may not be comprehensive. In particular for natural rubber, it is unclear whether all bulkbreak natural rubber shipments are included. Further, data from Panjiva cannot definitively say where an item was produced, only where the shipment originated. Nevertheless, Panjiva offers a fuller picture of the supply chain by providing a view into intermediate ports and transshipment locations.

Figure 7: Countries that export natural rubber to the US, crossed with the US ports that receive that natural rubber.[16]

Figure 8: Number of Natural Rubber Shipments to the US by Lading Port, Colored by Shipment Origin



4 Supply Issues

As stated above, synthetic rubber is a poor substitute for natural rubber in many uses. Many of these products are of great importance to the economy. This is certainly true of the main rubber product, tires. Both the commercial and defense sectors would quickly be under great strain if

[16] International Trade Management Division, "USA Trade Online." United States Census Bureau, 2023, https://www.census.gov/foreign-trade/data/index.html.

automobiles and planes were grounded due to a lack of tires. The recent declines in automobile manufacturing due to a sudden shortage of computer chips give us an idea of the impact that would have.

There is also a national security component. To start with, in addition to tires, many other military products depend largely on natural rubber supplies.[17] The vulnerability is increased by the fact that China already plays a major role in both the supply and demand of natural rubber. Given China's determination to challenge U.S. international leadership and the prospects of military action in Taiwan or nearby shipping lanes, it is even more important that the U.S. act to safeguard national security.

Latex is referred to as a critical agricultural product in the Critical Agriculture Materials Act (Public Law 95-592 as amended.) In addition, the European Union recently placed natural rubber on its list of critical raw materials due to its importance in the aerospace, textile, automotive, and health sectors.[18] Unfortunately, a number of potential disruptions threaten future supplies of this essential commodity. While most of them are uncertain, the combination of a high probability that one or more will happen, together with the economic impact of such a shortage, make it important for policymakers to act now to minimize the ultimate impact of such an event.

4.1 Increase in Demand

Prior to the COVID epidemic, a number of sources predicted that rising demand for natural rubber would soon begin to exceed supply.[19] The supply of natural rubber is limited by the fact that rubber trees can only grow in tropical regions. The most suitable growing areas are between 25 to 28 degrees Celsius with annual rainfall above 1,500 millimeters. Rubber trees take seven to ten years to produce a crop. In addition, traditional methods of expanding areas of cultivation face growing opposition from environmentalists due to concerns about deforestation. The European Union has already enacted the EU Deforestation Regulation, which will be implemented by the end of 2024. The regulation requires commercial users of rubber and other products to trace the origins of their raw material to ensure that it did not result in deforestation. Rubber trees also face competition from other crops such as palm oil. Low prices cause some small producers to over-tap their existing trees, leading to stress, but they give them no incentive to plant new trees. Labor shortages are also a concern.[20]

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[17] "The Innovative Uses of Rubber in the Military [Infographic]. White Cross Rubber Products website, April 17, 2016, https://www.wcrp.uk.com/news/innovative-uses-rubber-military-infographic/#:~:text=From%20use%20in%20fuel%20tanks%2C%20long-term%20weapon%20and,in%20our%20defence%20in%20one%20way%20or%20another; Taylor, William, March 22, 2024, "How is Rubber Used in Military?" The Gun Zone website, https://thegunzone.com/how-is-rubber-used-in-military/.

[18] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Critical Raw Materials Resilience: Charting a Path Towards Greater Security and Sustainability*, March 9, 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474.

[19] Cornish, Katrina, "Alternative Natural Rubber Crops: Why Should We Care?" *Technology and Innovation*, vol. 18, 2017, doi.org/10.21300/18.4.2017.245.

[20] Arias, Marina and van Dijk, Peter J. "What is Natural Rubber and Why Are We Searching for New Sources? *Frontiers for Young Minds*, July 19, 2019, https://kids.frontiersin.org/articles/10.3389/frym.2019.00100.

In contrast, demand for rubber tires and other products is expected to increase with economic growth, especially in developing countries. The movement toward electric vehicles will contribute to this trend since the weight of the batteries causes more wear on tires.

4.2 South American Leaf Blight

More than 2,500 plants produce natural rubber, but the world currently relies almost exclusively on rubber trees.[21] As we discussed earlier, rubber trees are monoclonal plants in that all are progeny of trees the British planted in Singapore and South America. This makes the trees very susceptible to disease. Brazil no longer produces much natural rubber. The reason is South American Leaf Blight (SALB). Unlike other diseases, SALB not only kills existing trees, but it also makes the land inhospitable to replacement trees, destroying the area's status as a producer of natural rubber. Vulnerability is also increased by the common practice of planting trees close together without ground crops in between. In 1928. Henry Ford established Fordlandia in Brazil to try and produce his own rubber in the Amazon rain forest, The trees were planted too closely together: the resulting SALB destroyed the crop, and no rubber was ever produced. Brazil's rubber production has never recovered.[22]

Despite elaborate procedures to protect Asian producers, increased travel between South America and Asia may eventually result in the disease's spread. Infections could also be deliberate, which is why SALB has been included in a list of biological weapons.[23] One widely respected researcher has been quoted as saying that if SALB were to make it to Asia the disease could wipe out most of the world's natural rubber supply in short order.[24] Rubber trees have also been threatened by other diseases. Pestalotiopsis leaf-blight fungi are currently reducing yields by 25% across roughly 0.4 million hectares of rubber in Indonesia, and multiple leaf-fall diseases are affecting China, Indonesia, Thailand, Malaysia, Sri Lanka, and India.[25] Climate change could aggravate this problem. A recent study correlated a significant upward trend in average mean temperature for Southeast Asian growing areas with an increase in rubber defoliation. It concluded that there is a strong possibility that climate change is responsible for the emergence of a new Rubber Leaf Fall disease.[26]

4.3 Climate Change

According to the *2017 U.S. Climate Science Special Report*, if yearly emissions continue to increase rapidly, by the end of this century global temperatures will be at least 5 degrees Celsius

[21] "How is Natural Rubber Made?" Apple Rubber website, https://www.applerubber.com/blog/how-is-natural-rubber-made/.

[22] McCoy, Terrence, "Utopia to Blight: Surviving in Henry Ford's Lost Jungle Town," *Washington Post*, July 28, 2023, https://www.washingtonpost.com/search/?query=fordlandia.

[23] Lieberei, Richard, "South American Leaf Blight of the Rubber Tree (Hevea spp.): New Steps in Plant Domestication Using Physiological Features and Molecular Markers," *Annals of Botany*, November 2007, https://doi.org/10.1093/aob/mcm133.

[24] "Innovative New Technology Could Boost US Rubber Production," *SciTechDaily*, January 28, 2024, https://scitechdaily.com/innovative-new-technology-could-boost-us-rubber-production/.

[25] Warren-Thomas, Eleanor, et al. "Rubber's Inclusion in Zero-Deforestation Legislation is Necessary but not Sufficient to Reduce Impacts on Biodiversity," *Conservation Letters*, 2023, http://dx.doi.org/10.1111/conl.12967.

[26] Azizan, F.A., et al., "Rubber Leaf Fall Phenomenon Linked to Increased Temperature," *Agriculture, Ecosystems and Environment*, 352, 2003, https://www.sciencedirect.com/science/article/pii/S0167880923001901.

higher than recent levels.[27] Given the narrow temperature range for growing rubber trees (25-28 degrees Celsius) and the heavy dependence on rainfall, it seems inevitable that climate change will have a large impact on natural rubber supplies. Rising water levels could also present a real problem, inundating some production areas and changing the salinity of soils.[28] Although a recent paper concluded that "next to nothing" is known about the exact effect that warming will have on tree growth or yield, if the rise in temperatures is correct, it could displace almost all current production.[29] Although new areas might become more suitable for raising trees, concerns about deforestation and continued competition from other crops may limit geographical expansion.

HSSEDI recently measured this vulnerability. It first divided current production areas into four categories spanning from traditional to marginal suitability. It then used a climate model that predicted climate patterns including temperature and rainfall over the next three decades. It then recategorized geographical areas according to the climate predictions for 2050. Figure 9 shows current production areas ranging from most suitable (green) to least suitable (purple). Figure 10 shows projected suitability for 2050. The HSSEDI study found that expected climate changes would have a drastic impact on the suitability of existing fields. If the climate model is correct, overall production is likely to fall significantly in many parts of Southeast Asia. However, Equatorial Africa showed long-term sustainability for growing natural rubber.

[27] *Highlights of the Findings of the U.S. Global Change Research Program Climate Science Special Report,* https://science2017.globalchange.gov/chapter/executive-summary/#fig-3.

[28] Stanway, David, "Oil Shipments at Risk from Rising Sea Levels Think Tank Warns," Reuters, May 21, 2024, https://www.msn.com/en-us/money/markets/oil-shipments-at-risk-from-rising-sea-levels-think-tank-warns/ar-BB1mLNrG?ocid=BingNewsSerp.

[29] Gohet, Eric, et al., "Worldwide Climate Typologies of Rubber Tree Cultivation: Risks and Opportunities Linked to Climate Change," In *Natural Rubber Systems and Climate Change, Proceedings and Extended Abstracts from the Online Workshop*, June 23-25, 2020, FTA Working Paper, May 2021, https://www.cifor.org/publications/pdf_files/FTA/WPapers/FTA-WP-9.pdf.

Figure 9: Rubber Growing Regions in Year 2025[30]

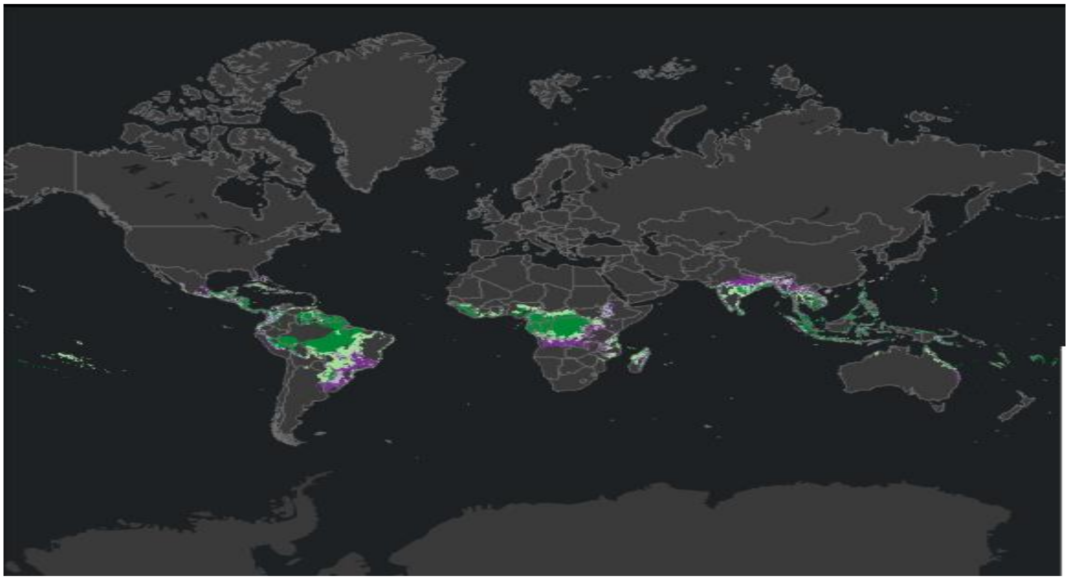
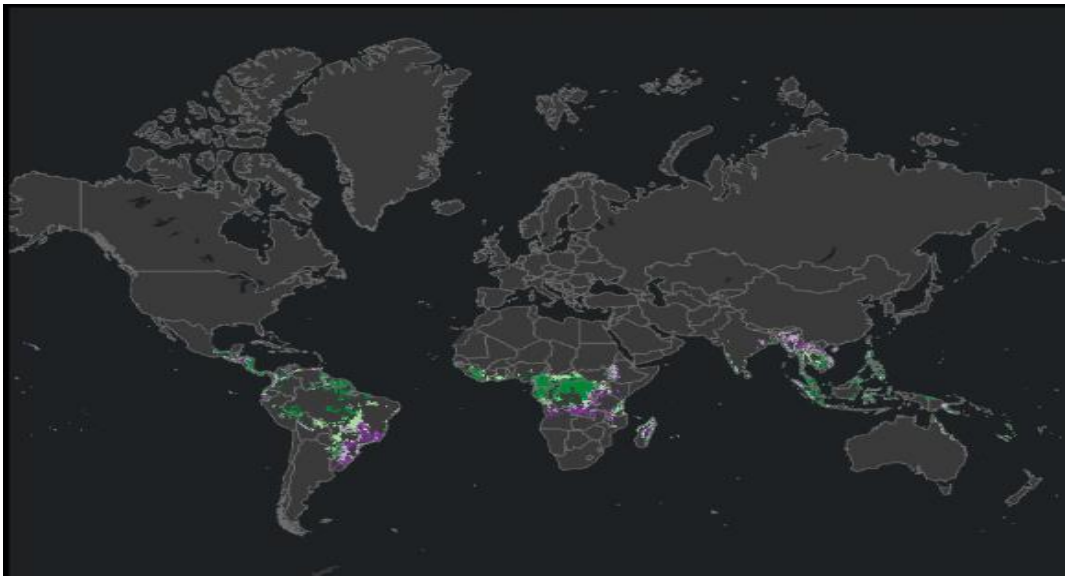


Figure 10: Rubber Growing Regions in Year 2050[31]



[30] Weber, Kristy and Habib, Joshua "The Effects of Climate Change on Future Natural Rubber Suitability," January 10, 2024.

[31] Weber, Kristy and Habib, Joshua, "The Effects of Climate Change on Future Natural Rubber Suitability," January 10, 2024.

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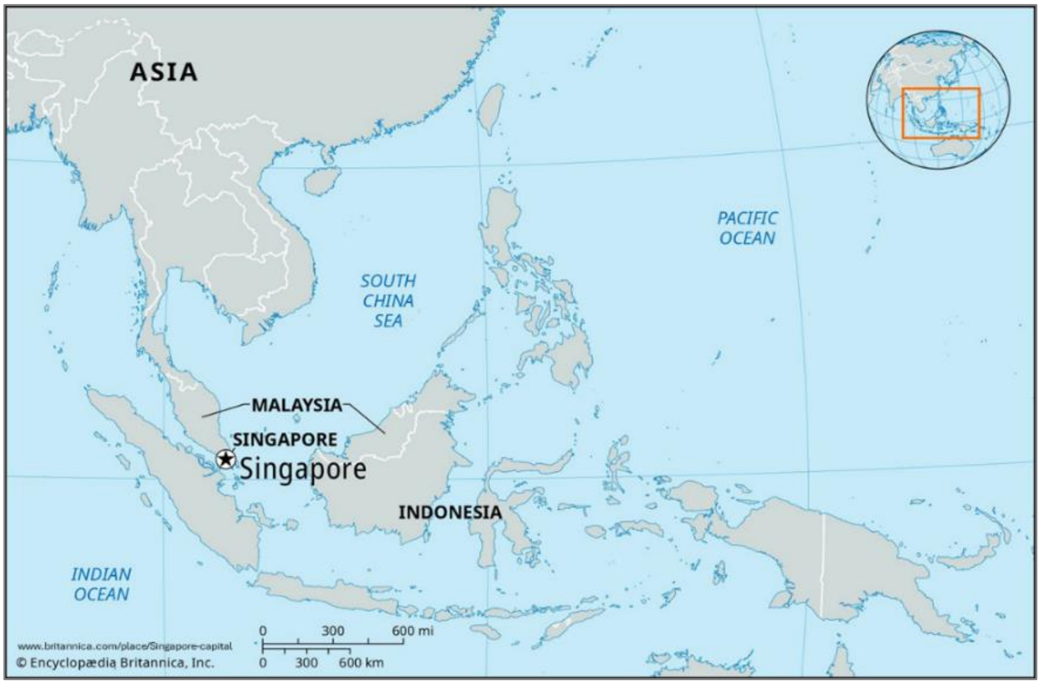
4.4 Threats to Shipping

A major consequence of the geographical concentration of natural rubber supply is the fact that in some cases an event might seriously affect both major producers of rubber, and thus the entire world. As it turns out, the vast majority of shipments must traverse a set of narrow sea lanes (See Figure 11). Despite international law, China claims jurisdiction over many of these routes and has occasionally exerted force against other nations to press its claims. Recent military attacks on shipping vessels by Houthis in the Middle East show the extra risk and costs that can occur when traditional shipping lines are threatened.

Figure 11: The Area Surrounding the South China Sea[32]

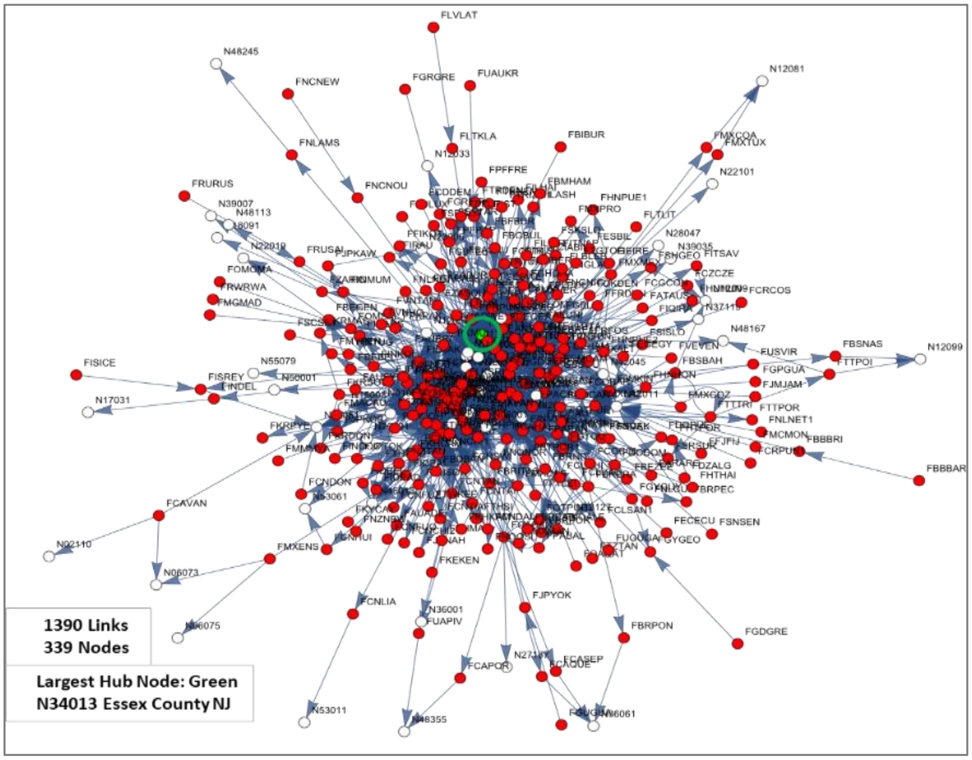


4.5 Structure of the International Supply Chain

HSSEDI conducted a network analysis of the natural rubber supply chain to reveal key structural characteristics of rubber imports into the United States. Figure 12 shows a network view of foreign exports of natural rubber into 53 U.S. counties for the period January 1, 2022, to November 1, 2023.

[32] Encyclopaedia Britannica, Inc, https://www.britannica.com/place/Singapore-capital.

Figure 12: International Natural Rubber Supply Chain Network[33]



The project's data science team mined the Panjiva platform to create a dataset of foreign-to-U.S. natural rubber shipments involving 286 foreign ports from 111 foreign countries that can reach 53 U.S. counties. Overall, 57 percent of the world's foreign countries participate in the global flow of natural rubber[34].

In Figure 12, the 53 white nodes are U.S. counties and labeled as Nxxxxx, where xxxxx denotes the county's Federal Information Processing Standard (FIPS) code. The 286 red nodes are foreign ports. For example, node FAEJEB denotes F (Foreign Node), Foreign Country: Arab Emirates (AE), Foreign Port: Port of Jebel Ali (JEB).

Table 1 shows the top 10 U.S. counties (nodes) that receive natural rubber from multiple foreign countries, as measured by the degree of the node. In general, the degree of a node is equal to the number of connections it has towards and from other nodes (inlinks plus outlinks). Since the U.S. does not export natural rubber, outlinks from a U.S. county are zero and hence this is not a column in Table 1.

[33] HSSEDI analysis of data from Panjiva Inc.

[34] There are 195 countries in the world today. This total comprises 193 countries that are member states of the United Nations and 2 countries that are non-member observer states: the Holy See and the State of Palestine, Encyclopaedia Britannica, Inc https://www.britannica.com/story/how-many-countries-are-there-in-the-world.

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Table 1: Top 10 U.S. Counties that Receive Natural Rubber[35]

Rank	Node	Degree (Inlinks)	County	State
1	N34013	77	Essex	NJ
2	N13051	67	Chatham	GA
3	N06037	59	Los Angeles	CA
4	N51710	56	Norfolk City	VA
5	N36047	53	Kings	NY
6	N48201	52	Harris	TX
7	N45019	48	Charleston	SC
8	N06001	38	Alameda	CA
9	N22071	35	Orleans	LA
10	N24510	33	Baltimore City	MD

In Table 1, Essex County NJ (green node in Figure 12) leads the top 10 list with 77 foreign ports from 39 countries exporting natural rubber to container ports in Newark NJ. Essex County has a significant and extensive highway, rail, and air transportation infrastructure. Newark Liberty International Airport is a major commercial airport operated by the Port Authority of New York and New Jersey.

China has the greatest number with 9 ports (12 percent) that directly ship natural rubber to Essex County NJ. Overall, across the supply chain network in Figure 12, it can be shown that 26 U.S. counties in 19 states receive natural rubber from at least one of 20 Chinese ports.

In Table 1, the number of inlinks simply reflects the structure of the network, in terms of the number of foreign ports that bring natural rubber into a U.S. county. Inlinks do not necessarily correlate to the economic value or weight of natural rubber entering that county. Inlinks are available pathways, such as New Orleans or Charleston, for the flow of natural rubber into the U.S. that could be marshalled as alternative routes of entry in circumstances where adverse events (risks) cripple, or shutdown, high volume (e.g., dollars, weight) receiving U.S. ports.

Singapore is a major transshipment hub for managing the global flows and prices of natural rubber. Table 2 shows the 15 foreign ports that are most active in shipping natural rubber around the world, with Singapore leading the list in connections. All top 10 U.S. counties directly receive natural rubber from Singapore. The following takes a deeper look into the inlinks to and outlinks from Singapore.

[35] HSSEDI analysis of data from Panjiva Inc.

Table 2: Top Foreign Flows for Natural Rubber[36]

Rank	Port/Country	Node	Degree	InLinks	OutLinks
1	Singapore, SG	FSGSIN	52	19	33
2	Antwerpen, BE	FBEANT	45	29	16
3	China, CN	FCNCHI1	40	0	40
4	Hong, Kong, HG	FHKHON	38	9	29
5	Shanghai Pt, CN	FCNSHA	35	13	22
6	Busan, KR	FKRBUS	34	13	21
7	Yantian Pt, CN	FCNYAN2	33	17	16
8	Ningbo Pt, CN	FCNNIN	31	12	19
9	Vietnam, VN	FVNVIE	31	2	29
10	Yangshan Pt, CN	FCNYAN1	29	16	13
11	Valencia, ES	FESVAL	29	16	13
12	India, IN	FININD	29	0	29
13	Thailand, TH	FTHTHA	29	0	29
14	Algeciras, ES	FESALG	27	19	8
15	Vung Tau, VN	FVNVUN	27	15	12

Table 3 lists the inlinks and outlinks to and from Singapore. The inlinks show the foreign port/country that is the shipment origin of natural rubber into FSGSIN Singapore; that is, Singapore receives natural rubber from the ports of these countries. These are countries that may ship natural rubber they have acquired, or have organically grown (e.g., Indonesia, India, Thailand). An example would be FTHTHA Thailand-to-FSGSIN Singapore.

[36] HSSEDI analysis of data from Panjiva Inc. Node FCNCHI1 China showing 0 inlinks is an artifact of the Panjiva data. Panjiva has shipments where "China" (not a specific port, just the country China) is labeled as the "shipment origin". For a foreign port to have an inlink, it must be listed as the "port of lading" on a shipment, and "China" (not a specific port) is never listed in the port of lading. China FCNCHI1 only having outlinks means it's only listed in Panjiva as shipment origin, and never as the "port of lading." Note there are specific Chinese ports listed as a port of lading and that do have in-links.

Table 3: Singapore Inlinks and Outlinks[37]

Inlinks to Singapore		Outlinks From Singapore			
Node	Country	Node	Foreign Country	Node	US County/State
FAUAUS	Australia, AU	FBEANT	Antwerpen, BE	N12086	Miami-Dade, US, FL
FBDBAN	Bangladesh, BD	FCNNIN	Ningbo Pt, CN	N13051	Chatham, US, GA
FBEBEL	Belgium, BE	FCNSHA	Shanghai Pt, CN	N13127	Glynn, US, GA
FCACAN	Canada, CA	FCNSHE	Shekou Pt, CN	N22071	New Orleans, US, LA
FCLCHI	Chile, CL	FCNXIA	Xiamen Pt, CN	N24510	Baltimore City, US, MD
FCNCHI1	China, CN	FCNYAN2	Yantian Pt, CN	N34013	Essex, US, NJ
FGBUNI	United Kingdom, GB	FEGDUM	Dumyat (Damietta), EG	N36047	Kings, US, NY
FHKHON	Hong Kong, HK	FESVAL	Valencia, ES	N45019	Charleston, US, SC
FIDIND	Indonesia, ID	FHKHON	Hong Kong, HK	N48201	Harris, US, TX
FININD	India, IN	FKRBUS	Busan, KR	N51710	Norfolk City, US, VA
FJPJAP	Japan, JP	FLKCOL	Colombo, LK	N53033	King, US, WA
FKHCAM	Cambodia, KH	FMYJOH	Johor Bahru, MY	N53053	Pierce, US, WA
FKYCAY	Cayman Islands, KY	FMYPOR	Port Klang (Pelabuhan Klang), MY	N06001	Alameda, US, CA
FLKSRI	Sri Lanka, LK	FMYTAN	Tanjung Pelepas, MY	N06037	Los Angeles, US, CA
FMYMAL	Malaysia, MY	FPACOL	Colon, PA		
FNONOR	Norway, NO	FPAMAN	Manzanillo, PA		
FPHPHI	Philippines, PH	FTHLAE	Laem Chabang, TH		
FTHTHA	Thailand, TH	FTWKAO	Kaohsiung, TW		
FVNVIE	Vietnam, VN	FVNVUN	Vung Tau, VN		

Table 3 shows the outlinks from Singapore as the shipment origin country. Singapore sends natural rubber to the listed foreign ports of lading (e.g., FBEANT Antwerpen, Belgium) and to the listed U.S. counties/states containing ports of unlading (e.g., Essex NJ). There can also be intermediate ports along the way between Singapore and the final destination of the shipment.

The network analysis further revealed that a cycle exists in the shipments of natural rubber between Singapore and Hong Kong. Shown in Figure 13, this cycle traverses through the South China Sea. Significant territorial disputes in this region persist. They continue to threaten the continuity of natural rubber exports from nearby producer countries, especially the world's top producer nations Thailand, Indonesia, and Vietnam.

[37] HSSEDI analysis of data from Panjiva Inc.

Figure 13: A Cycle in the Flow of Natural Rubber
Between Singapore and Hong Kong

Motivated by recent clashes in the South China Sea between the Chinese and Philippine Coast Guards[38], HSSEDI utilized a Structural Gravity Model of trade to understand how a potential conflict in the South China Sea would impact global trade in natural rubber. Indonesia and Thailand accounted for nearly half of the global rubber exports in 2022, and both rely on shipping lanes that pass through the South China Sea. This section first describes the gravity model of trade before describing how a South China Sea blockage was modeled. The section concludes by presenting the modeling results, discussing the caveats of the model, and the lingering questions as a result of the model.

The structural gravity model of trade is the 'workhorse' model of international trade economists.[39] The term "gravity" comes from the observation that international trade mirrors the physical law of gravity. Countries that are located closer to one another and have larger economies trade more than smaller countries that are located further apart. This mirrors the law of gravity in physics, which describes how the gravitational force between two objects is stronger for objects with greater mass and weaker when the objects are further apart. The

[38] For example, see https://apnews.com/article/fd76fcfcbcfcfdce5eb81c9422e8216c

[39] Yotov, Yoto V. et al., "An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model," World Trade Organization and the United Nations, 2013, https://www.yotoyotov.com/files/book.pdf.

observation that this relationship applies to international trade data is not coincidence either; the gravity model of trade can be justified using many theoretical models of trade that feature the reasonable assumption that shipping costs increase in distance. HSSEDI applied this model to trade in rubber products and modelled distances using the shortest maritime shipping distance between countries.[40] This allowed HSSEDI to estimate the rate at which natural rubber trade between two countries decayed as the maritime distance between the countries increased.

To model an escalatory scenario of maritime conflict in the South China Sea, HSSEDI identified the shipping lanes that intersected the South China Sea and would become partially unnavigable. This blockage would apply indiscriminately to all shipments, even Chinese vessels, because passage would be too dangerous for all commercial trade for up to one year, the unit of analysis for this annual trade data. HSSEDI then recalculated the shortest maritime distance between all countries after removing these routes. Figure 14 plots the intersection of these shipping routes with the South China Sea and ports that are completely exposed to the South China Sea. The closing of these ports implies that some countries, such as Vietnam and Thailand, would completely lose their access to maritime shipments. HSSEDI simulated two scenarios for a partial and full South China Sea blockage to provide relative estimates due to various levels of conflict.

The first partial blockage scenario is included to account for the fact that access to these countries could potentially be facilitated by ground shipments to unexposed ports in neighboring countries. The second scenario assumes that access to all these ports is fully blocked by the maximum level of conflict restricting all trade for up to one year. The impact that these scenarios would have on shipping distances from rubber producers to the United States is presented in Figure 15. The dark-blue bars represent the shortest distance a shipment must travel to get to the U.S. assuming the South China Sea is not blocked.[41] The light-blue bars represent the distance that the shipments must travel under the scenario where the exposed ports are only partially blocked. The effect of the fully blocked port scenario is to make the distance traveled for the three “boxed” countries in Figure 15 (Thailand, Cambodia, and Laos) prohibitively high, effectively blocking all trade with these countries. Currently, the rubber market relies on Singapore as a central market, as identified in the HSSEDI network analysis. If the area were blocked for one year, it may be possible for the market to adjust or shift operations to other ports and routes over time, but this would require significant agility by many small rubber production firms. The analysis did not consider some of the adjustments that might occur. It would be worth examining potential adjustments in the future to understand contingencies of these scenarios.

[40] Data on production comes from FAO, “Crops and Livestock Products.” United Nations, License: CC BY-NC-SA 3.0 IGO, 2023. Data on trade comes from the BACI database, Gaulier, Guillaume and Zignago, Soledad, “BACI: International Trade Database at the Product-Level (The 1994-2007 Version), CEPII Working Paper, (October 2010), https://ssrn.com/abstract=1994500 or http://dx.doi.org/10.2139/ssrn.1994500.

[41] Distances are only plotted for the countries that would see any change in their minimum shipping distances to the United States under a South China Sea scenario. Rubber producers, such as Guatemala, that see no change in their shipping distance to the U.S. are also included in the analysis.

Figure 14: The South China Sea and Maritime Shipping Lanes[42]

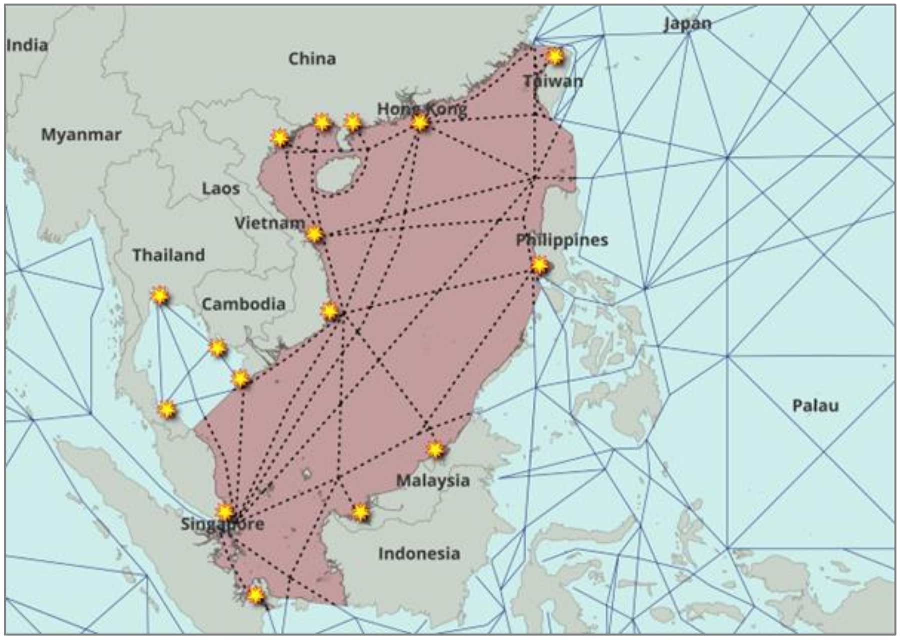
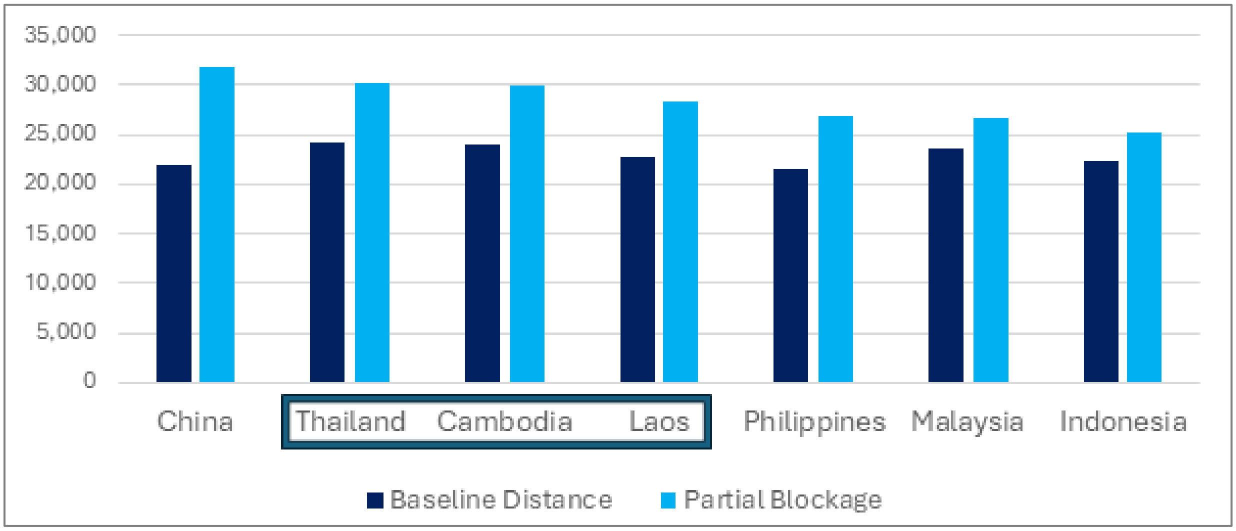


Figure 15: Estimated Change in Shipping Distances to the U.S. [43]



The Structural Gravity model quantifies how these increased shipping distances translate into higher shipping costs, and how global trade adjusts in response to the increased cost.

[42] The green lines represent the shipping lanes in our data. The red area is the South China Sea, and the dashed lines represent the shipping lanes that pass through the South China Sea. The yellow stars represent ports that are completely reliant on the South China Sea to access the global maritime shipping network according to Eurostat: https://eurostat.github.io/searoute/.

[43] The vertical axis presents distances in kilometers. In the full blockage scenario, the three countries in the boxed area would see their shipping distances to the U.S. increase to an insurmountable level, while the remaining countries' distance to the U.S. would be the same as in the partial blockage scenario.

Importantly, the model accounts for changes in prices and the "economic remoteness" of importers and exporters.[44] Figure 16 and Figure 17 show how the change in the transport costs between countries would impact the prices charged by exporters from each natural rubber producer. The partial scenario would see exporter prices change anywhere from a 33% increase to a 9% decrease, while the full scenario would see much more drastic impacts on the prices charged by exporters, highlighting the importance of the region as a global supplier.

The largest price increases are concentrated in exporting countries that rely on the South China Sea to export their products across both scenarios. Since it is more expensive to ship products out of these markets, the global supply of rubber is restricted, leading to increased prices. Figure 18 and Figure 19 plot the changes in global import quantities under the two restrictions. The impact of the partial scenario on rubber import quantities varies from a 28% increase in rubber imports to a 73% decrease. Many of the countries that see their imports increase in this scenario are rubber producers that are not as exposed to the South China Sea and benefit from the scarcity created by the shock (countries such as Guatemala and Ghana). Vietnam and Malaysia also benefit from the partial shock. The South China Sea restriction makes it more difficult to export out of the region, which intensifies intra-regional trade. Finally, it is also clear from Figure 19 that the full blockage scenario would drastically limit access to natural rubber for all countries across the globe. This is largely because Thailand, the largest rubber producer in the world, lacks any alternative ports to divert shipments away from the South China Sea. The complete removal of these shipments from world supply causes prices to soar even if Indonesia manages to ship out of its smaller southern ports. Figure 20 decomposes how U.S. import quantities of natural rubber from each natural rubber supplier would be affected by the shock under the partial block scenario. Under the full block scenario, the U.S. would see its imports fall from each partner by more than 90%.

A few caveats regarding this modelling effort are worth mentioning. The largest is that the two scenarios only simulate how a South China Sea disruption would impact trade in natural rubber products. In reality, a disruption in the South China Sea would impact trade in other industries that could cause further changes in the rubber trade. The second caveat is that the model does not include data on domestic absorption or recycling of existing natural rubber supplies. This matters for countries that both produce and import natural rubber. For example, China might offset some of its import losses by using more domestically grown rubber.

The model demonstrates how critical access to the South China Sea is for securing natural rubber imports, and it also leaves some important questions for future analysis. For example, the analysis does not look at how the disruption will impact manufacturing production across the globe. The analysis also does not consider how synthetic rubber could be used to offset the losses of access to natural rubber. In addition, there are policy levers that could be investigated in future work. For example, how can partnerships with African and Central and South American nations help reduce global reliance on Southeast Asian countries and the South China Sea?

[44] Anderson, James E., Larch, Mario, and Yotov, Yoto v. "GEPPML: General Equilibrium Analysis with PPML," *The World Economy*, vol. 41, no. 10, pp. 2750–2782, 2018, doi.https://doi.org/10.1111/twec.12664.

Figure 16: The Impact of a South China Sea Scenario on Exporter Prices – Partial Blockage[45]

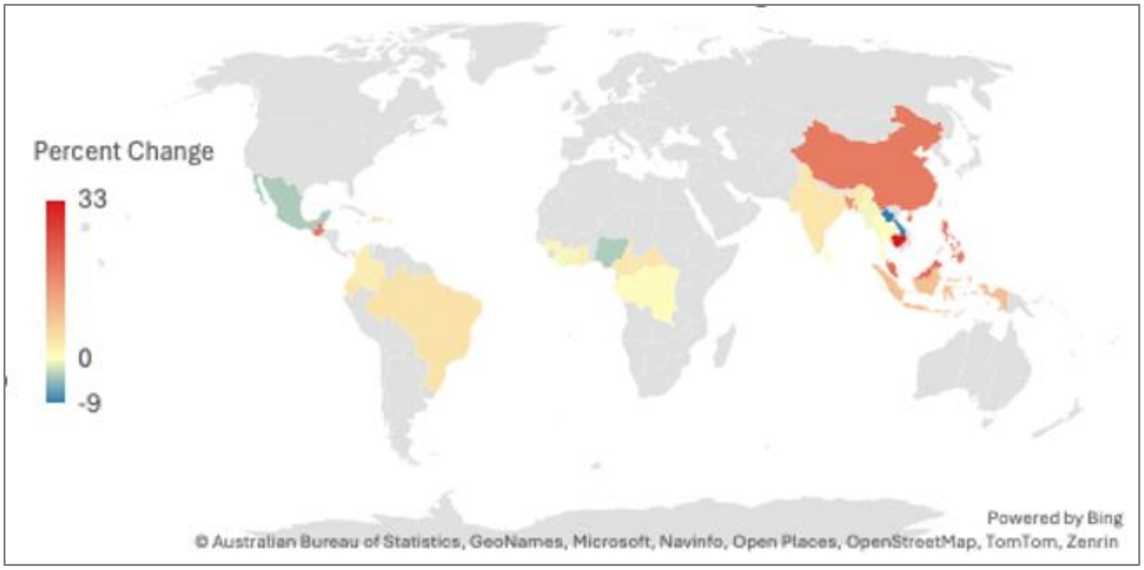


Figure 17: The Impact of a South China Sea Scenario on Exporter Prices – Full Blockage

[45] The figures estimate how 2018 natural rubber prices would change under the two South China Sea scenarios. Exporting countries are restricted to assume that only countries that produced natural rubber in 2018 are allowed to export natural rubber in the simulation. Data on production come from the United Nation's Food and Agriculture Organization. Import elasticity parameters for the model are taken from Soderbery, Anson, "Trade Elasticities, Heterogeneity, and Optimal Tariffs," *Journal of International Economics*, vol. 114, 2018, https://doi.org/10.1016/j.jinteco.2018.04.008.

Figure 18: The Impact of a South China Sea Scenario on Import Quantities – Partial Blockage[46]

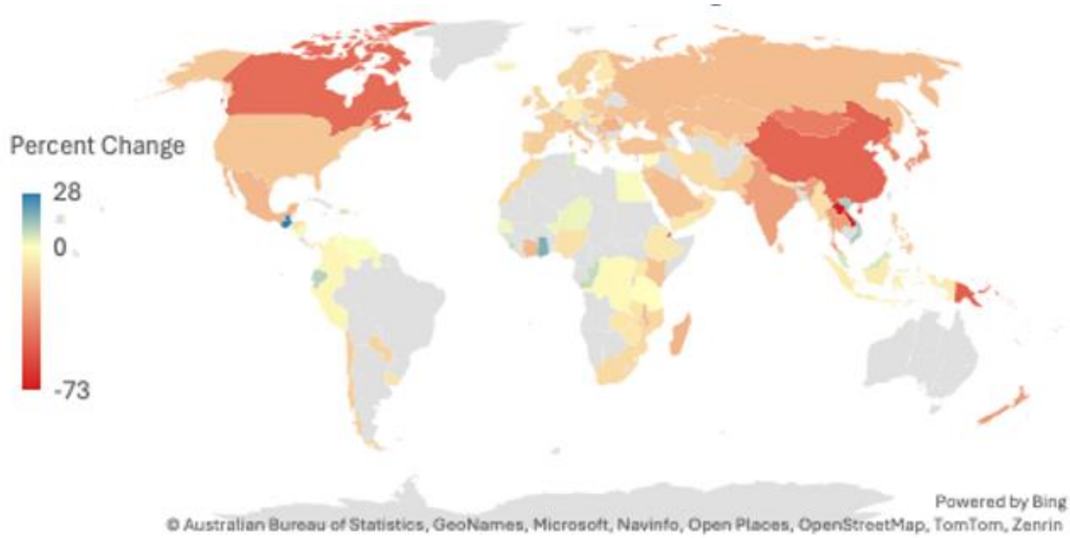
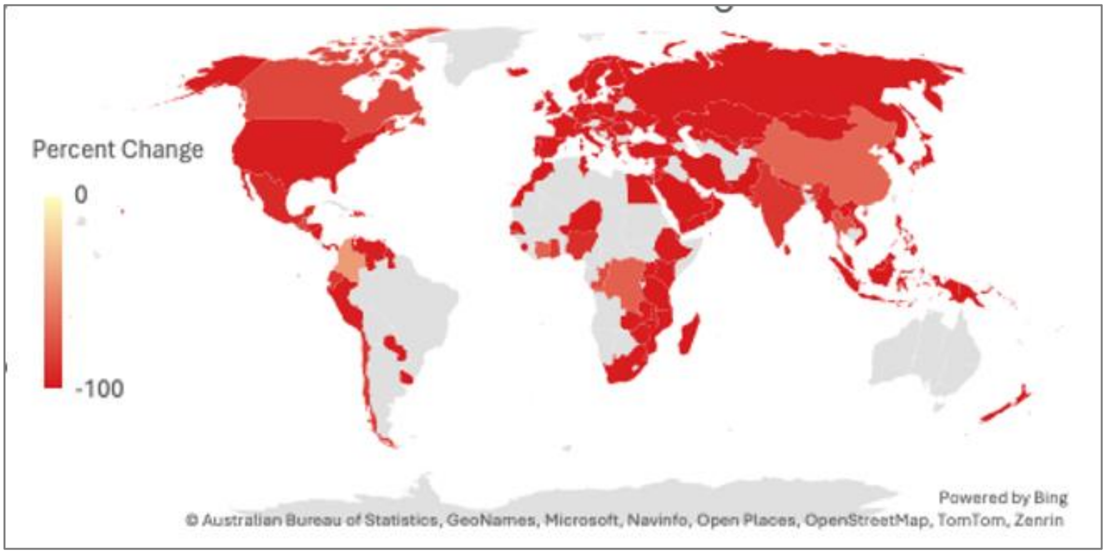
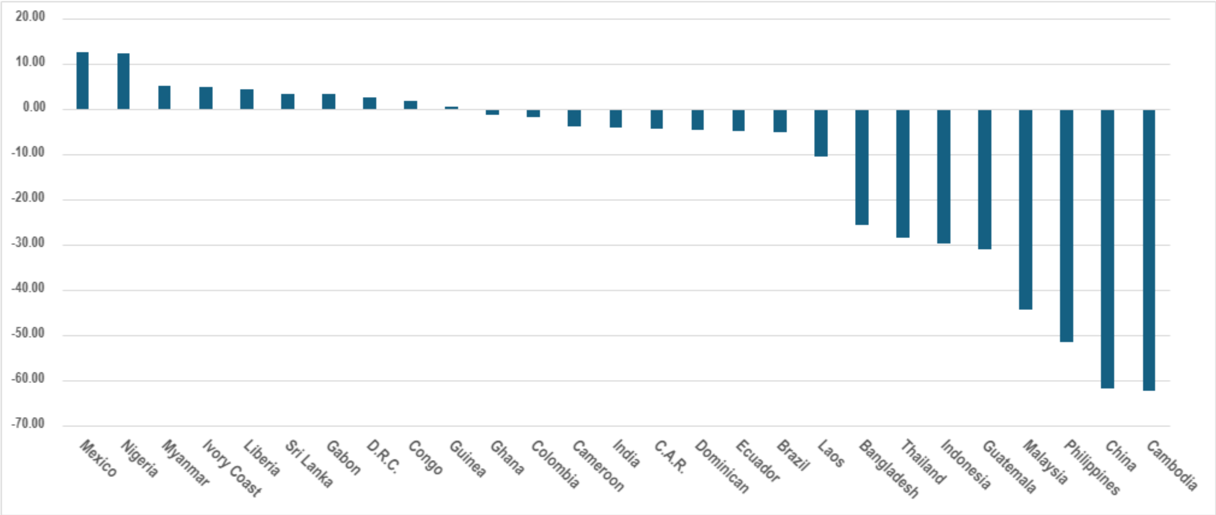


Figure 19: The Impact of a South China Sea Scenario on Import Quantities – Full Blockage



[46] This figure plots how natural rubber imports are estimated to change in response to a South China Sea scenario. The model is estimated using 2018 trade data from the United Nations. Importers are restricted to be the set of countries that imported natural rubber in 2018 and import elasticity parameters for the model are taken from Soderbery, Anson, "Trade Elasticities, Heterogeneity, and Optimal Tariffs," *Journal of International Economics*, vol. 114, 2018, https://doi.org/10.1016/j.jinteco.2018.04.008.

Figure 20: Percentage Changes in U.S. Imports by Exporter in Partial Scenario[47]



4.6 The Threat from China

As the world's leading user of natural rubber, China naturally has a large presence in global markets. However, it is not well understood how widespread and deep this presence is. Should China wish to cut off the supply of natural rubber to the United States, either because of hostilities or to preserve its own access in response to a shock to the supply chain, it would likely be able to cause severe disruption.

China's policy toward natural rubber extends beyond economics. A recent paper on China's approach to rubber concluded that China's domestic rubber cultivation would collapse without protective tariffs.[48] Rubber's role in China and neighboring countries includes opening remote frontiers and substituting rubber for opium as a crop. In fact, Chinese investors in its Opium Replacement Program are incentivized to procure a steady supply of rubber regardless of the price because they cannot risk having their allotment reduced. The paper quotes a Chinese CEO as saying: "one day, if there was an embargo, then Chinese companies would of course sell only to China."[49]

China's involvement in natural rubber markets also extends far beyond Southeast Asia. There are recent reports that China is purchasing rubber plantations and processing centers. A recent HSSEDI study looked at eight "nations of interest" that might be able to increase exports of natural rubber to the United States. It found that, of the eight, only Guatemala and Cameroon currently trade any significant amounts of rubber. Gabon and the Central African Republic trade

[47] This figure plots how U.S. natural rubber imports are estimated to change in response to the partial South China Sea scenario. The model is estimated using 2018 trade data from the United Nations. Import elasticity parameters for the model are taken from Soderbery, Anson, "Trade Elasticities, Heterogeneity, and Optimal Tariffs," *Journal of International Economics*, vol. 114, 2018, https://doi.org/10.1016/j.jinteco.2018.04.008.

[48] Lu, Juliet, "Strategic Resources and Chinese State Capital: A View From Laos," *Made in China Journal*, May 6, 2020, https://madeinchinajournal.com/2020/05/06/strategic-resources-and-chinese-state-capital/.

[49] Lu, Juliet, "Strategic Resources and Chinese State Capital: A View From Laos," *Made in China Journal*, May 6, 2020, https://madeinchinajournal.com/2020/05/06/strategic-resources-and-chinese-state-capital/.

minor amounts. Honduras, Central African Republic, and Nicaragua have almost no trade. In short, there are presently strong limits on how much the U.S. could source from other countries without rededicating itself to those relationships.

The HSSEDI study also identified hundreds of Chinese companies involved in the natural rubber trade. In Africa, in particular, it appears that China is creating an integrated vertical relative to natural rubber in which it owns plantations, production, manufacturing, chemicals, and shipping. The ownership pattern is often hidden amid a web of other corporations.

Guatemala is a promising source for additional natural rubber. The researchers were able to determine that three of the top five natural rubber shippers from Guatemala have already set up trade relationships with Chinese-owned companies in the U.S. and across the world. The Chinese government is the ultimate owner of 548 companies in 45 countries active in the plastics and rubber manufacturing industry. Of these, 71 companies are in the United States.

China's involvement in the rubber industry should be seen as part of a larger effort to control the world's shipping logistics. At a congressional hearing in 2019, the chair of the U.S.-China Economic and Security Review Commission testified that at least two-thirds of the world's container ports are owned by the Chinese or supported by Chinese investments, including at least two in the U.S.[50]

This widespread presence may not signal any ill intent. But China is a voracious user of natural rubber. It does show that China, concerned with natural rubber growing environments, is pursuing a proactive approach to securing natural rubber supplies wherever they occur, while also creating more value-added, and using commercial ties to increase its foreign influence. China has also made acquisitions of natural rubber to support its national stockpile. Meanwhile, the United States seems to be acting on the assumption that rubber markets will work with complete efficiency, unimpeded by either natural events, economic shocks, or international rivals. This is a high-risk assumption.

5 Potential Key Components of a More Proactive Policy

The above analysis points to the need for a more proactive approach. This section discusses three that might make the largest difference. First, the federal government should reestablish a national reserve for natural rubber that it could release in response to a significant fall in supplies. Second, the government should fund additional research on alternatives to rubber trees. This includes expanding the uses of synthetic rubber, cultivating other sources of latex, and finding ways to combat disease. Finally, the U.S. should work to improve its relations with possible alternative producers of additional rubber supply, such as Guatemala.

5.1 Building a National Rubber Reserve

The federal government currently maintains strategic reserves of crude oil and helium. For several years it also maintained a large reserve of natural rubber. Prior to World War II Japanese control of Southeast Asia cut U.S. imports of natural rubber by 90 percent. At the same time, the

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[50] Gallagher, John, "Experts Warn of China's Influence at U.S. Ports," *FreightWaves*, October 22, 2019, https://www.freightwaves.com/news/experts-warn-of-chinas-influence-at-us-ports.

country was anticipating a drastic increase in the production of military vehicles and planes. To meet these demands the nation embarked on a national campaign to balance supply and demand.

In response to the situation, President Franklin Roosevelt appointed a three-person committee chaired by businessman Bernard Baruch and including the presidents of the Massachusetts Institute for Technology and Harvard University. The Baruch Committee issued a report in September 1942 stating that: "[w]e find the existing situation to be so dangerous that unless corrective measures are taken immediately this country will face both a military and a civilian collapse."[51]

The committee made several recommendations, including the formal establishment of a reserve. Other prominent measures included a national speed limit of 35 miles per hour as well as a gas rationing system designed to reduce the average milage per car to 5,000 miles per year. It also recommended mandatory tire inspections for retreads. Finally, the Committee oversaw a major increase in research and development with the goal of finding alternative sources for natural rubber, including the construction of several new production facilities. By 1945 the U.S. was producing about 920,000 tons of synthetic rubber, 85 percent of which was known as Government Rubber - Styrene.[52]

5.2 Expanded Research and Development

Two main alternative sources of rubber exist. Taraxacum kok-saghyz (TK) dandelion can be grown widely in many parts of the U.S. Guayule is a type of shrub grown in the Southwest. Research on expanding both as commercial sources of natural rubber has spanned decades without much success. But that could change.[53] Goodyear and Bridgestone have created tires out of TK dandelion and guayule respectively, however, presently there is not enough of either to impact the market significantly.[54] It is also unclear whether these alternatives will have all the unique characteristics of natural rubber, such as heat resistance. Moreover, there are no mass cultivation or production facilities and the chemical and physical characteristics of both are not fully established. Finally, agricultural trade-offs will also have to be considered as much more growing capacity will be required to scale these alternatives.

The Critical Agricultural Materials Act authorizes a program of research and development for guayule and other hydrocarbon-containing plants.[55] However, it has not resulted in major appropriations to fund the research. Nevertheless, both TK dandelion and guayule have

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[51] *Report of the Rubber Survey Committee*, September 10, 1942, Bernard M. Baruch, Chairman, 5, https://babel.hathitrust.org/cgi/pt?id=mdp.39015031328209&seq=3.

[52] American Chemical Society, *United States Synthetic Rubber Program: 1939-1945*, 1998, (Pamphlet), https://www.acs.org/education/whatischemistry/landmarks/syntheticrubber.html.

[53] "Innovative Tech Shows Promise to Boost Rubber Production in U.S." Ohio State University College of Engineering website, February 19, 2024, https://engineering.osu.edu/news/2024/02/innovative-tech-shows-promise-boost-rubber-production-us; Gesellschaft, Fraunhofer, "Natural Rubber from Dandelions," PhysOrg Website, June 8, 2015, https://phys.org/news/2015-06-natural-rubber-dandelions.html.

[54] "Goodyear to Develop Domestic Source of Natural Rubber," News Release, Goodyear website, https://news.goodyear.com/goodyear-to-develop-domestic-source-of-natural-rubber; "'Plant to Produce Rubber' Grown in Arid Regions – Guayule," Bridgestone website, https://www.bridgestone.com/technology_innovation/natural_rubber/guayule/.

[55] Critical Agricultural Materials Act, https://www.govinfo.gov/content/pkg/COMPS-10290/pdf/COMPS-10290.pdf.

experienced significant discoveries in recent years.[56] As part of its Partnerships for Climate-Smart Commodities Projects, the U.S. Department of Agriculture has awarded $35 million to a project to develop natural rubber from guayule.[57] Led by the University of Arizona, the project seeks to expand production of guayule in the Southwest. It will pay a per acre per year incentive for farmers and fund planting, harvesting and delivery of the crop to the processing facility. The project works almost exclusively with underserved and small producers and hopes to market the rubber to Bridgestone, which is providing more than $35 million in matching funds.

The promise of these efforts can also be seen by the application of the Greater Akron Chamber to lead a Technology Hub to develop a world-class region for producing environmentally friendly rubber and plastics.[58] The Hub is one of 31 national finalists for the Regional Technology and Innovation Hubs Program. Five to ten winners are likely to be announced in June or July 2024. Each will receive federal investments of $50 to $75 million. Given its momentum and commitments, the Hub is expected to grow even if it does not receive a grant in this round of funding.

The State of Ohio has also funded research and development at Ohio State University for TK dandelion. The main technical problem is that there is no easy way to get the latex out of the root. Significant progress would also require the construction of production facilities to scale up production to commercially viable levels. Guayule may be easier to harvest because the entire shrub can be used. Commercial production of either could displace other commercial crops, however. Still, given the experience from World War II, there are good reasons to expect that a major commitment of research and development will produce valuable alternatives to natural rubber.

Recycling could also benefit from additional federal funding for research and development. The Circular Rubber Platform, based in the Netherlands, is a new organization that is trying to work with members to improve the circularity of the supply chains for both natural and synthetic rubber.[59] Presently, almost no rubber is recycled. However, the organization's website argues that rubber recycling has not only been researched, but it has also been applied on an industrial scale for many decades. However, a lack of incentives has favored using virgin materials. This is slowly changing because of customer demands, new legislation, and concerns over sustainability.

5.3 Expanding Foreign Ties

China's position as the leading user of natural rubber and its geographical position in the vicinity of the world's major producers gives it significant influence in world markets. Although the

[56] Ware, Doug G., "Air Force Sees Chance to Cut Reliance on Foreign Supply Chain by Making Rubber out of Dandelions," *Stars and Stripes*, February 21, 2023, https://www.stripes.com/branches/air_force/2023-02-21/air-force-rubber-dandelions-9208349.html; "Innovative New Technology Could Boost US Rubber Production," *SciTechDaily*, January 28, 2024, https://scitechdaily.com/innovative-new-technology-could-boost-us-rubber-production/.

[57] "Partnerships for Climate-Smart Commodities Projects" USDA website, https://publicdashboards.dl.usda.gov/t/FPAC_PUB/views/PartnershipsForClimate-SmartCommodities/ProjectDetail?%3Aembed=y&%3AisGuestRedirectFromVizportal=y.

[58] "Sustainable Polymers Tech Hub Case for Designation", EDA website, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Sustainable-Polymers-Tech-Hub.

[59] Circular Rubber Platform website, https://circularrubberplatform.com.

United States may have trouble matching this influence, it can pursue more sensible policies to strengthen its support among leading producers.

A recent history of Chinese-Malaysian rubber trade describes how China carefully cultivated its relationship with Malaysia for decades. Despite active U.S. opposition including, ironically, U.S. attempts to impose an embargo of natural rubber exports to Communist China, the two countries gradually established significant trade in natural rubber. In contrast, the author portrays U.S. behavior as ruthless and selfish, refusing to alleviate the negative impact of its synthetic rubber exports or to support efforts to stabilize world prices.[60]

The U.S. should work to re-establish ties with other producers, especially those that might benefit from climate change. Current estimates point to Guatemala and certain areas in Africa and both Central and South America as potential growing spots in the future.[61] The United States should establish stronger ties and potential production agreements with those countries. Careful cultivation of both natural rubber and diplomatic ties could help produce regional economic security as well as local jobs and perhaps reduce the level of migration from those countries.

Another possibility would be for the U.S. to lead an effort to use the increased environmental tracing requirements to identify and work with land holders in Indonesia to increase their yields, which apparently lag those in Thailand.[62]

6 Conclusion

In a volatile environment a strategic miscalculation relative to the status of Taiwan could pose a serious geopolitical threat. Moreover, China's push for control of the region has also left the waters and related shipping lanes of the South China Sea contested.

The Chinese demand for natural rubber is growing along with expanded investments in autonomous and electric vehicle production. China is often undersupplied as it seeks to fulfill its needs. Though China has tried to influence the world by expressing concerns about deforestation, its behavior belies these concerns.

China has quietly been procuring plantations in Africa and is building an industry vertical to ramp up its ability to produce natural rubber in Africa and Latin America. It also now presently controls more than 40% of the chemicals required to make synthetic rubber.

These factors leave the United States at risk militarily and economically. Natural rubber is in more than 50,000 products, including many military applications, and the U.S. is reliant on Southeast Asia for more than ninety percent of its supply. We no longer have control of all the chemicals to make synthetic rubber. The U.S. position is risky and is likely unsustainable.

As a result, the United States should consider taking affirmative steps as this paper has outlined, to better position ourselves for the potential of an economic shock to the natural rubber market.

[60] Yao, Yu and Guo, Youxin, "The Sino-Malaysian Rubber Trade, 1950-80: A Global History," *Journal of Global History,* (2023), https://doi.org/10.1017/S1740022823000220.

[61] Castellanos, Daniel Salazar, "Latin America's Rubber Industry Looking to Bounce on to the World Stage," March 5, 2022, https://www.bloomberglinea.com/2022/03/05/latin-americas-rubber-industry-looking-to-bounce-onto-the-world-stage/.

[62] Warren-Thomas, Eleanor, et al. "Rubber's Inclusion in Zero-Deforestation Legislation is Necessary but not Sufficient to Reduce Impacts on Biodiversity," *Conservation Letters,* 2023, http://dx.doi.org/10.1111/conl.12967.

This could mean re-establishing a strategic natural rubber reserve, seeking alternative sources for natural rubber including in Africa and Guatemala, investing in alternatives to rubber trees and domestically producing chemicals necessary for synthetic rubber production.

Alternatives to rubber trees like TK dandelion and guayule will require industry and federal government collaboration on several decisions relative to strategic investments and related trade-offs. We need to better understand how these alternatives can be scaled and how much current demand can be replaced. If these alternatives prove to be viable, complex issues will result concerning germplasm ownership, farm production and a host of scenarios where government and industry will have to work together quickly and collaboratively. We need to begin that planning process now.

The Chinese will continue to ensure their access to natural rubber, but they also realize that natural rubber is an Achilles Heel for the United States. Unless we take steps to adequately protect our market access, the U.S. risks a potential economic crisis, and we will not have the same tools that we had during World II to manage such a crisis. That result could potentially be catastrophic and so action may be warranted because the price for inaction may be severe.

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