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The World War II U.S. Rubber Famine

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ABSTRACT

By April 1942 Japan had cut off almost all U.S. supplies of natural rubber, the one strategic material for which the country had effectively no domestic sourcing. The resulting shortage aggravated downward pressure on manufacturing productivity and seriously jeopardized military capability. The risks that this would happen, widely foreseen, could have been mitigated by more or earlier stockpiling, subsidization of domestic plant-based sources of latex, or development of a synthetic rubber industry. At the time of Pearl Harbor, each route had been pursued in a very limited fashion or not at all. This paper explores why, highlighting the outsized role played by businessman/politician Jesse Jones, as well as the multiple channels through which the rubber famine adversely affected the country's wartime economy.

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Introduction

The main cause of the sharp drop in U.S. manufacturing productivity between 1941 and 1945 was the transition from making goods in which manufacturers had a great deal of experience to those in which they had little.[1] The effects of the product mix changes would have been serious even had there been no additional disruptions. But there were additional disruptions. Aside from Pearl Harbor, U.S. territory did not suffer from major attack by enemy forces during the war. A Japanese submarine ineffectively shelled oil storage tanks near Santa Barbara in 1942 and in 1945 six people were killed in Oregon by an incendiary bomb carried by balloon on air currents from Japan.[2] Nevertheless, actions by both Germany and Japan seriously disrupted the U.S. economy through means other than simply forcing changes in the product mix. The Germans did so via U-boat predation, shutting down the 'tanker pipeline' that brought petroleum and petroleum products from East Texas and Louisiana to the Eastern seaboard.[3]

The Japanese did so by overrunning Singapore in February 1942 and then rapidly taking control of almost all Southeast Asian sources of natural rubber. This deprived the United States of 97 percent of its supply of the one strategic material in which it had effectively no domestic sourcing. Other inputs, such as manila hemp, tin, and a range of strategic metals and minerals also faced wartime supply disruptions.[4] But, for the United States, no other material involved such limited alternate sources of supply or opportunities for substitution. There were simply no satisfactory substitutes for rubber in a variety of critical uses, particularly tire carcasses and treads, the ultimate end use of 70 percent of rubber inputs.[5]

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[1] Subsequent learning only partially counterbalanced these downward pressures, and the product mix continued to change during the war. Alexander J. Field. *The Economic Consequences of U.S. Mobilization for the Second World War* (New Haven, 2022); "The Decline of U.S. Manufacturing Productivity between 1941 and 1948," *Economic History Review* 73 (2023): 1163-1190.

[2] Robert M. Neer, *Napalm, An American Biography* (Cambridge, MA, 2013), pp. 39-40.

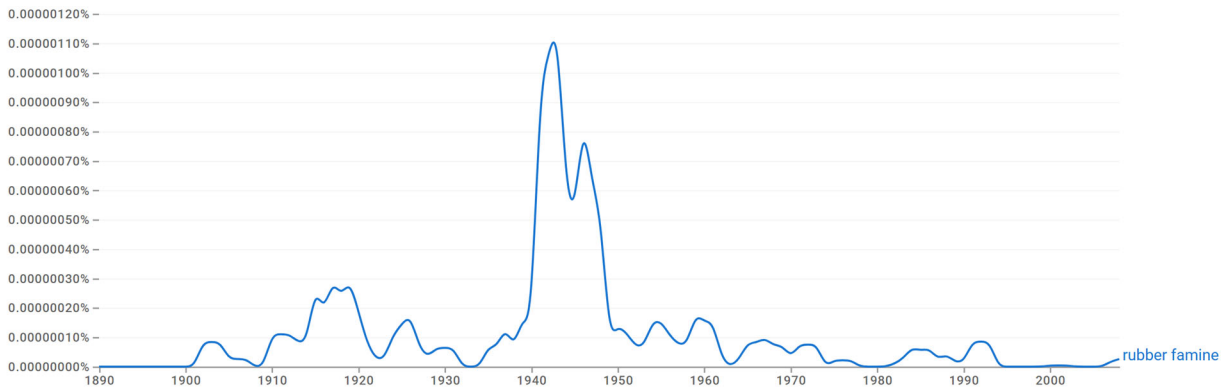
[3] Field, *Economic Mobilization*, ch. 4.

[4] A 1940 report of the Army Navy Munitions Board classified fourteen materials as strategic: antimony, chromium, coconut shell char (used in gas masks), manganese (essential in steel production), manila fiber (hemp, essential for naval mooring cables (hawsers) and available from only a small part of one island in the Philippines), mercury, mica, nickel, quartz crystal, quinine (anti-malarial), rubber, silk, tin, and tungsten.

[5] Field, *Economic Mobilization*, ch. 3; Frank Howard, *Buna Rubber: The Birth of an Industry* (New York, 1947), p. 207; U.S. Tariff Commission, *Crude Rubber*: *Brief Summary of the Current situation with Special Reference to the Effects of War Conditions on United States Imports* (Washington, 1940), pp. 1, 2.

The passage of time has dulled awareness of the famine and its consequences. The challenge it represented was nonetheless omnipresent during the war, as a search for the terms using Google's n-gram viewer reveals: Figure 1 shows a boomlet during World War I (Britain cut off East Asian imports for two weeks in 1914 until the U.S. agreed not to reexport to Germany) dwarfed by a spike peaking in 1942, the chaotic year in which the prospect of the United States losing the war seemed most possible.

Figure 1: Frequency of References to 'Rubber Famine' in English Language Texts



Note: The plot displays, by year, the frequency of ngrams (in this case a 2gram) in a corpus of printed works in English, in other words, what fraction of 2grams match the identified text string. The search is case insensitive, and the annual data are smoothed (smoothing parameter = 1; the data for each year include that year's count averaged with the count of the year before and the year after).

The subsequent decline of interest in or awareness of the shock has affected even knowledgeable scholars, who have downplayed the challenge it posed to the U.S. economy and Allied war efforts, and the ways in which the threat of cutoff could have been more effectively mitigated. The index to one of the most authoritative accounts, Richard Overy's *Why the Allies Won*, contains no entry at all for rubber. The material is mentioned once in the text and there is a reference to a "shortage of tyres", but it is to a shortage affecting *German* forces following the D-Day invasion.[6] Other authors recognize the challenge posed, but treat the U.S. synthetic rubber program as obviously the best response and one almost

[6] Richard Overy, *Why the Allies Won* (New York, 1995), pp. 199, 227.

miraculously and effortlessly willed into existence, giving less attention to alternatives and short shrift to the defects in the design and execution of the program. Maury Klein, for example, acknowledged the severe challenge to the economy of the risk of cutoff, and the potential benefits of stockpiling, but ignored the possible relief an earlier commitment to guayule might have made. And he gives Jesse Jones a pass, not acknowledging his foot dragging on both stockpiling and synthetic rubber.[7] Paul Koistinen's analysis is closer to that in this paper, but he also ignores guayule as an option that might realistically have provided an alternate supply of latex had the federal government provided earlier funding for a program of cultivation.[8]

One finds in none of these authors or elsewhere a comprehensive account of the main options for mitigating the risk (and then actuality) of rubber cutoff, why each of these had been pursued in only a limited fashion or not at all at the time of Pearl Harbor, and why the U.S. synthetic rubber program, ultimately chosen as the main route to mitigation, was not the miraculous success it is so often portrayed as. The famine's history starkly illuminates a policy dilemma still with us: how much insurance should a country carry when it depends heavily on interruptible foreign sourcing of a strategic input? Despite ex post claims to the contrary, it was widely anticipated before Pearl Harbor that conflict with Japan would very likely result in the loss of almost all supplies of natural rubber. It was also understood that there were three principal means, beyond suppression of consumer demand and encouragement of the use of reclaim,[9] whereby the U.S. might mitigate the risk: 1) accumulate a large strategic stockpile; 2) subsidize

[7] Maury Klein, *A Call to Arms: Mobilizing America for World War II* (New York, 2013, pp 78, 98, 234). Klein provides no evidence for his assertion that "Nearly everyone agreed that it would cost less to build the synthetic plants than to buy a year's worth of rubber, assuming it could be had" (p. 234).
[8] Paul Koistinen, *Arsenal of World War II: The Political Economy of American Warfare, 1940-1945* (Lawrence, KS, 2004).
[9] Reclaim had historically been discouraged in the United Kingdom because of concern about reducing demand for Empire-produced natural rubber. In the U.S., in contrast, reclaim was often seen as the first line of defense against shortages or high cartel prices of natural. U.S. Department of Commerce, *Materials Survey*: *Rubber*. Compiled for the National Security Resources Board. (Washington, DC, 1952), p. IV-4. With the imposition of rubber rationing, however, the supply of reclaim dropped precipitously (William Haynes and Ernest M. Hauser, *Rationed Rubber, and What to Do About It*, (New York, 1942), ch. 7). Rubber can be reclaimed several times, its quality deteriorating in a process partially compensated for by mixing with new supplies of natural rubber. In 1940 natural rubber tires were good for 25-30,000 miles, all-reclaim tires less than half that (U.S. Tariff Commission, *Crude Rubber*, p. 30;

domestic production of alternative plant-based sources of latex, in particular guayule; or 3) develop a synthetic capability. Between 1942 and 1945 the rubber famine aggravated downward pressures on U.S. manufacturing productivity. From a military standpoint, the choices leading to this result threatened the ability of the United States and the United Nations to prevail in the conflict -- much more so than the controversial decision to move the U.S. Pacific fleet from San Diego to Pearl Harbor in March 1940.

This paper considers why the strategic stockpile was so low. It explains why the passage of legislation in 1942 providing $45 million for an Emergency Rubber Program based largely on guayule cultivation was too late. And it documents how the design and structure of the synthetic rubber program and the delays in initiating butadiene plant construction exposed the country to potential disaster. In the process, it considers the outsized role played by businessman/politician Jesse H. Jones, as well as the multiple channels through which the rubber famine adversely affected the country's wartime economy and military capability.

Stockpiling

Stockpiling was the simplest way to protect against the consequences of cutoff. Warehousing entailed no biological/botanical uncertainty about how well a particular plant species might grow under U.S. or friendly country soil and climate conditions. Unlike synthetic rubber, it did not rely on untested engineering or chemical processes. The costs were predictable, and a strategic reserve provided almost perfect substitutes for timely imports of natural rubber. The U.S. stockpile increased from 125,800LT in 1939 to its peak in April 1942 (634,152LT) with arrival of shipments on their way to the U.S. as Japanese forces completed their seizure of Southeast Asian exporting sites.[10] This reserve, less than twice

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U.S. Senate, *Hearings before a Special Committee Investigating the National Defense Program*. *Part II. March 5, 24, 26, 27, 31, April 1, 2 3, 7, 1942. Rubber.* Seventy-Seventh Congress. (Washington DC, 1942), p. 4553; J. M Ball, *Reclaimed Rubber: The Story of an American Industry* (New York, 1947).

[10]Vernon Herbert and Attilio Bisio, *Synthetic Rubber: A Project that Had to Succeed* (Westport, CT, 1985), pp. 9-10, 14-15; U.S. Rubber Reserve Company, *Report on the Rubber Program, 1940-1945* (Washington DC, 1945), pp. 5, 16. Imports and inventory stocks of rubber were, for historical reasons, reckoned in long tons (LT; 2,240 pounds).

what it had been at the end of the Depression year 1932 (379,000 LT), remained woefully inadequate given the wartime needs of the country and its allies.[11]

The U.S. consumed 591,000LT (long tons) of natural rubber in 1939. By 1941, as the country's negative output gap closed, U.S. consumption had increased to 781,259LT, and imports had grown to 1,023,631LT as stocks were accumulated. Then Singapore fell, followed, as war planners and many others had long feared, by almost complete supply cutoff. In the next four calendar years (1942-45), the United States imported 583,053LT, barely half of what it brought in during 1941 alone. At the end of 1944, natural rubber inventories stood at just 93,650LT. Import flows were lowest in 1943 but end-of-year inventory stocks reached their lowest point in December 1944. Had the joint U.S. – British Combined Raw Materials Board not reallocated output from Ceylon (Sri Lanka) – the one Southeast Asian supplier still under Allied control – to the U.S. and the Soviet Union, the U.S. would have run out in that year.[12]

The eventual availability of synthetic rubber in quantity did not end the rubber famine. Synthetic had to be blended with natural in the manufacture of almost all products, and in some cases synthetic could not be used at all.[13] During World War II the United States never escaped the threat of running out of rubber, which stood as a sword of Damocles over the entire economic and military effort. In 1944 the country almost ran out of natural rubber and would have had the war continued into 1946.[14]

Jesse Jones

The inadequate level of the 1942 stockpile owed much to the judgments and decisions of a powerful Washington insider simultaneously occupying multiple institutional positions. Jesse Jones headed the Reconstruction Finance Corporation from 1933 through 1939, when he resigned as chair to assume the post of director, Federal Loan Agency. The RFC, along with an alphabet soup of other federal agencies,

[11]U.S. Tariff Commission, *Crude Rubber* (Washington D.C. 1940), p. 24; Gerald T. White, *Billions for Defense: Government Financing by the Defense Plant Corporation during World War II* (University AL, 1980), p. 41.
[12] Paul Wendt, "The Control of Rubber in World War II," *Southern Economic* Journal 13 (1947): 203-27, 204.
[13] White, *Billions*, p. 204.
[14] U.S. War Production Board, *Wartime Production Achievements*, p. 94.

remained under Jones' purview throughout the war, with close associates nominally running them. In 1940 he became concurrently (and after a special enabling act of Congress), Secretary of Commerce, and in 1942, at its inception, a member of the War Production Board. Because, up to a very generous debt ceiling, Congress had given the RFC authority to borrow on the full faith and credit of the United States by issuing its own bonds, either directly or through the Treasury, Jones and the RFC had a spending and lending authority more flexible than that of Congress itself. "You'd better see Jesse" was common advice in wartime Washington for those wanting funding for a new program.

After the war, Jones justified his reluctance to build the stockpile more rapidly on the grounds that if he had bid aggressively, pushing up the world price by even a few cents, the rubber growers, rather than shipping more, would "begin to hold their stocks in the expectation of still higher prices.[15] The defect in this justification is revealed in the next chapter of his memoir, which allows that he held a powerful weapon to use in negotiations with the cartel: the threat that the U.S. would develop synthetic rubber. As he wrote in a letter to Roosevelt on 16 September, 1940: "they are extremely anxious to sell the rubber and are not enthusiastic about our building synthetic plants.[16] Neither, for that matter, was Jones, but those with whom he was negotiating didn't need to know that.

In 1940 and 1941, Jones downplayed the likelihood of cutoff, in contrast to the judgments of many other knowledgeable observers, who believed it was high. Jones, moreover, was wrongly optimistic that if Southeast Asian shipments were cut, supply from friendly countries in Latin America and elsewhere would prove highly elastic. Above all, he was allergic to 'wasting' taxpayer money, and was therefore

[15] Jesse H. Jones, *Fifty Billion Dollars: My Thirteen Years with the RFC (1932-1945).* Written with Edward Angly, (New York, 1951), p. 397.
[16] Jones, *Fifty Billion Dollars*, p. 405; Steven Fenberg, *Unprecedented Power: Jesse Jones, Capitalism, and the Common Good* (College Station, TX, 2011), p. 361. See also Jones' testimony before the Truman Committee (U.S. Senate, *Hearings*, pp. 4530-31).

reluctant to spend on the stockpile because he doubted how much was needed and because he awaited the price of natural rubber falling to lower levels.[17]

An example of his application of a 'banker's mentality' to a national security problem was his reaction when a government warehouse storing rubber in Fall River, Massachusetts burned down on 12 October, 1941, destroying at least 15,000LT of crude rubber. Jones reportedly exclaimed, in a remarkable display of near-sightedness, given how critical the size of the stockpile would be less than half a year later, "Good thing we have it insured."[18] Commercial policies were simply inadequate to insure against the possible real consequences of loss of U.S. access to Southeast Asian supplies of natural rubber.

As RFC head in the 1930s Jones played an effective role in liquifying and recapitalizing the U.S. banking system through loans and purchases of preferred stock, a program that ended up (as he reminded his correspondents and the public repeatedly) yielding profit to the U.S. Treasury.[19] His default practice, from which he could sometimes be dislodged if pressed hard enough by others with power, was to loan conservatively on good collateral at robust rates that made it unlikely the RFC would lose money. What mattered most was avoiding an accusation that he had disbursed funds in what might be judged an imprudent fashion. Jones "had no philosophical objection to state capitalism as long as it wasn't bad capitalism…. Jones would not risk money on bad loans."[20] That record, and his reputation for probity and conservative management, was the key to the high levels of esteem in which he was held by members of

[17] "Jones was much more skeptical of [the defense effort's] urgency and more concerned that RFC funds not be wasted" (White, *Billions,* p. 39).
[18] *New York Times*, 13 October 1941.
[19] This was true even though stabilizing the banking system did not lead to the large expansion of commercial credit Jones and others thought necessary for recovery. Between June 1933 and December 1936, member bank loans rose only from $11.3 to $11.6 billion, The industrial expansion of 1936-7 appears to have been financed largely by retained earnings, stimulated in part by government spending on naval construction and public works, as well as various relief payments, including the World War I veterans' bonus payments and RFC loans to finance rebuilding following floods and other natural disasters. James S. Olson, *Saving Capitalism: The Reconstruction Finance Corporation and the New Deal, 1933-1940* (Princeton, 1988), pp. 168, 179, 187. The recapitalization work may have been necessary for recovery, but it was not sufficient.
[20] Olson, *Saving Capitalism*, pp. 156, 204.

both political parties in Congress. This, along with his close personal relationship with Roosevelt, underlay the power and influence he wielded in Washington.

Jones made a fortune in lumber, tobacco, newspapers, banking, and as a hotel and commercial real estate developer in Houston and New York City, playing a major role in the development of Houston as a city and inland port. Politically astute, he operated at the pinnacles of American economic and political society, despite having left school after the eighth grade. Intimately familiar with borrowing and lending, both as a consumer and provider of financial services, he held strong views about what constituted sound business and banking practice. Herbert Feis wrote that he and others at the State Department wished to pursue purchases more aggressively, but were thwarted by Jones, who placed sharp limits on what Rubber Reserve would pay.[21] Jones "hoarded the Rubber Reserve Corporation fund, searching for bargains that did not exist because war was inflating commodity prices."[22]

Jones enjoyed positive press during most of the thirteen years he spent in Washington. But his management of the threat and then actuality of rubber shortage coincided with the worst press and Congressional criticism he received during his career, as well as a physical altercation with longtime antagonist Eugene Meyer, former head of the Federal Reserve System, first head of the RFC, and publisher of the *Washington Post*. Meyer had published an editorial two weeks earlier sharply critical of

[21] Herbert Feis, *Seen from E. A.: Three International Episodes* (New York, 1947); cited in Hugh Rockoff, "Getting in the Scrap: The Salvage Drives of World War II." Working Paper, 15 March, 2000. The minutes of the Rubber Research Company from its first meeting on 29 June, 1940 through the end of 1941 focus almost exclusively on contractual issues of price, shipping, insurance and damage claims involving rubber acquired by the RRC's buying committee, composed of representatives from the big four rubber manufacturing companies. A willingness to offer greater flexibility in the maximum price the RRC would pay (18.5 cents per pound) would almost certainly have resulted in a larger peak stock in April 1942, given the large gap between Southeast Asian production capacity and the cartel controls limiting exports and thus production.

[22] O'Neill, *Democracy at War,* p. 79. See also Donald M. Nelson, *Arsenal of Democracy: The Story of American War Production* (New York, 1946), p. 39.

Jones' management of the rubber crisis.[23] Another important antagonist was syndicated columnist Drew Pearson.[24]

Aside from stockpiling, Jones also balked at funding a synthetic rubber program, beyond perhaps the construction of small experimental facilities.[25] For all his success in the private sector and then as a government banker, Jones lacked the experience to design, let alone evaluate the merits or size of a proposed synthetic rubber industry. When confronted with a program designed by an oil company with an interest in its evolution, Jones acted to stall its forward momentum and appears to have influenced or at least reinforced Roosevelt in taking (at least initially) a similarly skeptical view of its necessity. Questions about the design of Standard Oil of New Jersey's proposed program can justifiably be entertained, but blocking its advance demanded, under the circumstances, articulation of something to take its place. Jones exhibited little interest in assembling on his staff the disinterested technical competencies that might have helped him develop an alternative.

By November 1940 a program designed around Standard Oil's blueprint had advanced to a planning stage and was moving forward. In February 1941, Jones cancelled it, defending his action on the grounds that he did not want to waste government money on "expensive plants," except in an "extraordinary emergency," which in his judgment did not then exist. Jones believed he knew oil (both the industry and the men) and acted, he thought, to protect taxpayers. On 26 February, 1941, Standard's CEO received the memo explaining this, which included the claim that the RFC had accumulated a stockpile of natural

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[23] William M. Tuttle, "The Synthetic Rubber "Mess" in World War II." *Technology and Culture* 22 (January 1981): 35-67, 35; Fenberg, *Unprecedented Power,* pp. 401, 406-10; Eugene Meyer, "*Mr. Jones' Appologia.*" Editorial in the *Washington Post*, 25 March, 1942, p. 10.

[24] Drew Pearson, *Washington Merry Go Round,* 10 March, 1942. Pearson reported that in summer 1941 the Navy and Maritime Commission wished to allow ships to unload Southeast Asian rubber in San Francisco rather than continuing through the Panama Canal to New York. Jones would not pay the extra cost of shipping the rubber across the country by rail. The consequence was that scarce shipping was unnecessarily tied up and less rubber could ultimately be brought into the country. https://digitalcollections.american.edu/Documents/Detail/the-washington-merry-go-round-march-6-1942/135406?item=154850.

[25] Howard, *Buna Rubber*, p. 131; Jones, *Fifty Billion Dollars*, p. 404; Robert A. Solo, *Synthetic Rubber: A Case Study in Technological Development under Government Direction.* Committee on the Judiciary, U.S. Senate, 85th Congress, 2nd session. (Washington D.C., 1959), p. 19; Koestinen, *Arsenal*, p. 158.

rubber sufficient "to carry us for three years." That claim, which could be supported only under the most unrealistic assumptions, was developed by William L. Clayton, Jones' deputy, and presumably reflected the judgments of his boss.[26] In March, Jones backtracked in response to protests about the cancellation, proposing that each of the Big 4 rubber product manufacturing companies build a small 2,500 ton per year demonstration plant to gain experience with copolymerization. But there was no funding for butadiene production, expenditures on facilities for the production of which would ultimately consume about half the government investment in the synthetic rubber program (construction of copolymerization plants cost about a quarter).[27]

In subsequent testimony before the Gillette Committee that year, Jones stated that "the RFC only carries out policies, it does not formulate them", which might have been true formally but was not so in practice.[28] Relying with great confidence on his own judgment, he ended up hamstringing both the stockpiling and synthetic rubber routes to remediation. In testimony before the Truman Committee in 1942, Jones also displayed strong skepticism about the merits of prewar efforts to develop guayule cultivation.[29] Guayule, the third route to mitigation, escaped some of Jones' restraining influence because it was in the Department of Agriculture's bailiwick, headed until 1940 by his rival Henry Wallace (who then became Vice President). Nevertheless, by the time funds were appropriated for guayule by Congress, it was too late.

A Counterfactual

[26] Clayton came to Washington in November 1940 to assist fellow Houstonian Jones as Deputy Federal Loan Administrator "with what proved to be a too conservative stockpiling of strategic materials" (White, *Billions,* p. 93).
[27] Samuelson, "The U.S. Government Synthetic Rubber Program, 1941-1955: An Examination in Search of Lessons for Current Energy Technology Commercialization," Working Paper MIT-EL 76-02WP, (Cambridge, MA, 1976) p. 7.

[28] Solo, *Synthetic Rubber*, p. 28.
[29] U.S. Senate, *Hearings*, p. 4548. For a more sympathetic view of Jones' actions, see Jonathan Marshall, *To Have and Have Not: Southeast Asian Raw Materials and the Origin of the Pacific War* (Berkeley, 1995).

The synthetic rubber program produced approximately three billion pounds (1.34 million LT) of synthetic during the war.[30] Most of this was GR-S, where it would substitute for natural rubber.[31] If the stockpile had been that much higher than its maximum in April 1942 (634,152LT), it could have substituted for the entire wartime output of the synthetic rubber program, with the additional bonus of avoiding the milling penalties of working with synthetic–natural blends in fabrication.

The world price of natural rubber remained at or below 20 cents a pound prior to U.S. entry in the war. Southeast Asian suppliers had, in the aggregate, substantial excess capacity, which is part of what had incentivized the creation of the two interwar cartel schemes. More could easily have been produced. We can assume that the U.S. would have continued to accept contractual language limiting its ability to dump its stockpile in the event it avoided war. Conclusion: About $600 million additional spending on stockpiling could have replaced the entire wartime output of the U.S. synthetic rubber industry (1.34 million x 2,240 x $ .20 = $600.32 million).

As of June 30, 1942, the U.S. stockpile was stored in 135 warehouses around the country.[32] These facilities needed temperature control, protection against UV damage from sunlight, and sprinkler systems with adequate water pressure. Labor requirements were modest – mostly armed security guards – as were requirements for interior furnishings or equipment, certainly compared to any of the synthetic plants constructed. Natural rubber in storage deteriorates but has a recommended shelf life of between three and five years. Standard storage costs were apparently $120 per ton in and out and $.50 per ton per month ($6 per ton per year).[33] In and out costs would have been $120*1.34 million = about $160 million. Add $20 million for storage of what would have been a declining stock over a four year period for total

[30] Jones, *Fifty Billion Dollars,* p. 401.
[31] A small amount was neoprene, a specialty rubber with good oil resistance that DuPont had made prewar, and a tiny amount was butyl, another specialty rubber developed prior to the war by Standard Oil of New Jersey, but not sold commercially. It had high gas impermeability and thus was well suited for inner tubes.
[32] "Crude Rubber in Storage and in Transit to Storage by Warehouse as of June 30, 1942." Mimeographed.. Jesse Jones papers, Library of Congress, Box 203.
[33] Warehousing costs are from correspondence regarding an RRC storage contract with the Shawnee Pottery Company in Zanesville Ohio. Jesse Jones papers, Library of Congress, Box 203.

warehousing costs of $180 million which would bring total acquisition and storage costs to $780 million, about the cost of construction of the 51 plants comprising the synthetic rubber program ($700M).

In addition to plant construction, the synthetic program required about $2 million a day to operate.[34] Calculating two years of expenses (365 x 2 x 2 = $1,460 million) brings us to a combined construction and operating cost of the U.S. synthetic rubber program of slightly more than $2 billion ($700 M +$1,460M), as much as was spent on the Manhattan project. Relying entirely on stockpiling could have resulted in net savings of approximately two thirds of a Manhattan Project ($2.160 billion - .780 billion = $1.38 billion). The lower cost of stockpiling is only part of the benefit that would have accrued to entering the war with a larger stockpile, which would have supplied a substitute that, in addition to avoiding the time and labor milling penalty, was far less risky in terms of if or when it could actually be accessed.

Other Foreign Sourcing and the Guayule Alternative

The loss of access to Southeast Asian rubber was potentially devastating to the United States because the country had virtually no domestic sources of latex and because there was hardly any supply elsewhere in the world not then under enemy control. Remaining annual production available to the United Nations from Africa, South America, or Mexico, could have satisfied just two weeks of U.S. consumption in 1941.[35] *Hevea brasiliensis*, the preferred source of natural rubber, requires a moist, warm climate generally found near the equator.

As compared with the exploitation of wild *hevea,* plantation cultivation offered the promise of higher yields per acre because of much higher density, and the opportunity to raise yields per tree through selective bud grafting and vegetative propagation from cuttings.[36] Plantation cultivation, however, had not

[34] Jones, *Fifty Billion Dollars,* p. 415.
[35] Wendt, "Control," p. 204.
[36] Whaley suggests that wild *hevea* could be expected to yield about 2.7 pounds per tree per year (300,000,000 trees yielding 50,000LT). W. Gordon Whaley, "Western Hemisphere Natural Rubber," *Torreya* 44 (1944). A more optimistic estimate of the potential yield of wild rubber from the hemisphere was 100,000LT (Caldwell, 'Rubber' p. 46) implying 5.4 pounds per tree annually, which would be more consistent with oft quoted remarks that plantation methods "tripled" the yield in comparison with wild.

and has not been successful anywhere in the Western hemisphere. Henry Ford made the most ambitious attempt, obtaining a land grant from the Brazilian government of 2.5 million acres located 600 miles up the Amazon and about 190 miles south of Santarém. Beginning in 1928 his organization planted seedlings on thousands of cleared acreage and built Fordlandia, a transplanted midwestern company town replete with schools, hospital, swimming pool, cafeteria, golf courses, and suburban housing for his managers.[37] His efforts were ultimately stymied by insensitivity towards his Brazilian workforce, but more fundamentally by a microorganism (*Microcyclus ulei)* that causes leaf blight and eventually killed the trees.[38] In 1934, acknowledging defeat, the company persuaded the Brazilian government to trade 700,000 acres of the original grant for a new site (Belterra) closer to Santarém, and began anew. It looked initially as if the second effort might be successful. But the resistant strains proved to be low-yielding, and the plantation continued to struggle with leaf blight. In 1945 Henry Ford II sold both parcels back to the Brazilian government at a loss to the company over the 17-year period of about $20 million.[39]

Ford's failures are consistent with the conclusion that the United States could not and cannot expect cheap plantation rubber to be grown anywhere in the Western hemisphere. Harvey Firestone had more success in Africa, persuading the Liberian government to grant him a 99-year lease on 1 million acres of

[37] Greg Grandin, *Fordlandia: The Rise and Fall of Ford's Forgotten Jungle City* (New York, 2010).
[38] The wild trees in the Amazon survive because they are dispersed (about one per acre); in plantations, their density invites attack. Almost all the rubber trees in Southeast Asia were and are genetically identical to those growing wild in Brazil.
[39] Grandin, *Fordlandia*; Gary and Rose Neeleman. *Rubber Soldiers: The Forgotten Army that Saved the Allies in WWII (*Atlglen, PA., 2017). During summer 1940 the Department of Agriculture, using $500,000 finally appropriated by Congress for this purpose (the request had been turned down three times before), sent four expeditions to Central and South America to survey possible sites for plantation *hevea* and conduct experimental plantings (U.S. Senate, *Hearings,* pp. 4944-46). This initiative, pushed by Henry Wallace, the department's head, might earlier have partially mitigated U.S. dependence on Southeast Asian supplies, but could not then remedy the impending rubber shortage, since the trees took 6-7 years to reach maturity. Bill Caldwell, "Rubber on the Rebound," *Esquire* 46 (1942), p. 113; Wendt, "Control," p. 205). Nor was there a simple solution to leaf blight, although it was hoped it could be addressed by selecting resistant strains of *hevea* (Whaley, 'Western Hemisphere, p. 20). Subsequently, spraying with copper or sulfur fungicides had some success (W. Gordon Whaley, 1948. "Rubber: The Primary Sources for American Production," *Economic Botany* 2 (Apr – Jun 1948): 198-216. When war came, the Emergency Rubber Project funded some *hevea* planting in Haiti, but, along with efforts to cultivate *cryptostegia*, initiatives in that country made no dent in the rubber famine.

Firestone's choosing and on them creating the world's largest rubber plantation.[40] Firestone's Liberian operations began in 1926, and continued to operate almost a century later, sometimes at reduced capacity depending on the state of the world rubber market and Liberian internal political conflict. After Pearl Harbor, Rubber Reserve contracted with Firestone for the entire output of the Liberian operation. In 1943, the year of the United States' lowest imports, these holdings supplied almost a quarter (23 percent) of a greatly reduced flow of imports, but this was never enough to account for more than about two percent of overall U.S. consumption.[41]

That left hemispheric wild rubber. In Spring 1942 the United States negotiated agreements with twenty-six South and Central American governments, calling for those countries to provide the U.S. (at a negotiated price) all their rubber production beyond that required for domestic consumption. Like the Liberian contract, this program succeeded in covering only a small fraction of U.S. wartime consumption needs.[42] U.S. consumption (synthetic and natural) totaled 488,535LT in 1943 and 710,783LT in 1944. Of this, Latin America provided 26,200LT in 1943 (5.4 percent) and 32,800LT in 1944 (4.6 percent). This contrasts with earlier confident predictions for 1942 of 75,000 to 100,000LT from Latin American wild rubber, and for 1943 and 1944 of 60,000LT and 120,000LT respectively. As Wendt concludes, "The Western Hemisphere natural rubber program was not a success."[43]

Neither wild nor plantation grown rubber in the Western hemisphere or Liberia would alleviate the U.S. rubber famine. After imports from Southeast Asia ceased to be available, stockpiling was no longer an option, and, setting aside synthetic rubber, the remaining possibility was to increase the cultivation within the United States of other plant-based sources of latex. The most promising of these was guayule (*Parthenium argentatum).* In the first decade of the twentieth century wild guayule had a record of

[40] Gregg Mittman, *Empire of Rubber: Firestone's Scramble for Land and Power in Liberia* (New York, 2021); Neeleman and Neeleman, *Rubber Soldiers*, pp. 17-18.
[41] Herbert and Bisio, *Synthetic Rubber,* p. 18; Wendt, "Control," p. 208.
[42] Neeleman and Neeleman, *Rubber Soldiers*, documents the often terrible conditions under which the 50,000 recruited to increase the wild rubber harvest labored and often died, but overstates the Brazilian contribution to the U.S. war effort.
[43] Caldwell, "Rubber," p. 46; Wendt, "Control," pp. 205, 227.

successful commercial exploitation by the Intercontinental Rubber Company (IRC), which numbered among its investors a pantheon of Wall Street notables, included Nelson Aldrich, Bernard Baruch, Daniel and Sol Guggenheim, Jacob Schiff, and John D. Rockefeller Jr. The IRC operation in Mexico, through its operating subsidiary, the Continental Mexican Rubber Company, harvested and then, using a capital-intensive process patented in 1904, extracted rubber from the plants. Polished stones in rotating drums crushed the leaves and stalks. The output was placed in settling tanks, where the rubber floated to the top and was then dried in sheets.[44] Production increased sharply between 1905 and 1910, and in the latter year guayule provided the raw material for almost a fifth (19 percent) of U.S. manufactured rubber goods. The IRC eventually controlled over 3.8 million acres in Mexico, giving it a practical monopoly of the shrub's natural habitat.

Wild guayule's contribution to U.S. rubber consumption in 1910 was impressive, but there are questions about how sustainable it might have been, given that extraction of rubber from the plant could be done only once, as opposed to *hevea*, which could be tapped again and again for decades. In any event, beginning in 1911 Mexican revolutionaries repeatedly disrupted operations at the Torréon facility, and in 1916 the IRC took seeds to the U.S. with the intent of converting the wild plant into a domesticated cultivated crop, planting acreage in southwestern Texas near Laredo, south of Tucson, Arizona and, in 1926, in Salinas, California. During the spring of 1930, following an invitation from the company, the U.S. Army detailed an obscure major named Dwight D. Eisenhower to visit IRC operations in California, Texas, and Mexico as part of a two-man team. The diary of his visit and his official report are available in his published collected papers.[45]

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[44] Jonathan Van Harmelen, "The Scientists and the Shrub: Manzanar's Guayule Project and Incarcerated Japanese American Scientists." *Southern California Quarterly* 103 (Spring 2021): 61-98, 70; Mark R. Finlay, *Growing American Rubber*: *Strategic Plants and the Politics of National Security* (New Brunswick, NJ, 2009).

[45] Daniel D. Holt, and James L. Leyerzapf, eds., *Eisenhower: The Prewar Diaries and Selected Papers* (Baltimore, 1998), pp. 117-138.

Eisenhower toured cultivated acreage in Texas and California (Salinas) as well as the remnants of the IRC facilities in Mexico used to process wild guayule, where he also observed the mixed success with attempts to reseed the semiarid terrain. Eisenhower was one of many who correctly feared what would happen in the case of war with Japan. As he observed in his 1930 report to the Assistant Secretary of the Army, "Should our sea communications with [Southeast Asia] be cut in an emergency, shortage of rubber in the United States would rapidly become acute".[46]

In his report, despite his earlier diary observations, he was no longer optimistic that market forces themselves would bring forth a large supply of irrigated guayule from independent farmers. Moreover, the market risks faced by the IRC made it unlikely that the company would undertake a major expansion on its own account, nor were there other companies in the U.S. with the experience in cultivation and processing that would likely do so in its stead. And he concluded that the United States could not rely on revival of a substantial supply of rubber from Mexican guayule due to the insecurity of property rights in that country and uncertainty about the success of efforts to reseed wild guayule.

These considered judgments lead him to propose subsidization of guayule cultivation in the United States, listing seven reasons why this might benefit the nation. The first was that it would reduce dependence on Southeast Asian supplies that could be interrupted by war or restricted by cartelization. He considered the employment benefits during a Depression of providing additional jobs for farmers, workers, and mechanics, and noted that in 1930 the U.S. was spending $200-300 million annually to pay for rubber imports, the top commodity import by value during the interwar period. He commented on the benefits of shifting acreage away from crops like cotton, corn, and small grains that produced more than the U.S. needed toward the production of an input for which the country was almost entirely dependent on imports. And he noted that the IRC had several decades of experience harvesting and processing guayule, that the plant had been studied extensively, and that the semiarid regions most suited to its cultivation

[46] Holt and Leyerzapf, p. 126.

were not well suited to the cultivation of other crops. Finally, he observed that adding even 10 percent to the world supply of rubber would drive down the price of *hevea*, which would benefit the United States to the degree it continued to import natural rubber. He therefore proposed that the government subsidize 400,000 acres of cultivated guayule. This would enable the annual production of about 71,400LT of natural rubber.

Eisenhower's report vanished into oblivion, its journey to a final resting place speeded on its course by the collapse of rubber prices in the worst years of the Depression.

A Second Counterfactual

A second counterfactual illustrates the difference implementation could have made. Suppose 100,000 acres had been planted per year beginning in 1935. Starting in 1939, a fourth of the cultivated acreage could have been harvested, processed, and replanted annually, with the harvest stockpiled. Between 1939 and 1945, this would have yielded an annual flow into storage of 71,400LT a year, making unnecessary the production of 428,400LT of synthetic rubber, about a third of total actual wartime production. This could have complemented a more aggressive pre-Singapore program of importation, requiring only a 1.5x increment to stockpiled imports that together with the guayule would have obviated the need for any synthetic, again with the advantage that guayule, unlike GR-S, and (along with imported stockpiled rubber), did not entail the time and labor milling penalty. Guayule was close to a perfect substitute for *hevea* in most uses, and superior in some. The costs of the guayule share of the replacement would have been higher than imported *hevea*, but there would have been some compensating reductions in warehousing costs, and the supply, since it came from the continental United States, would have been secure.

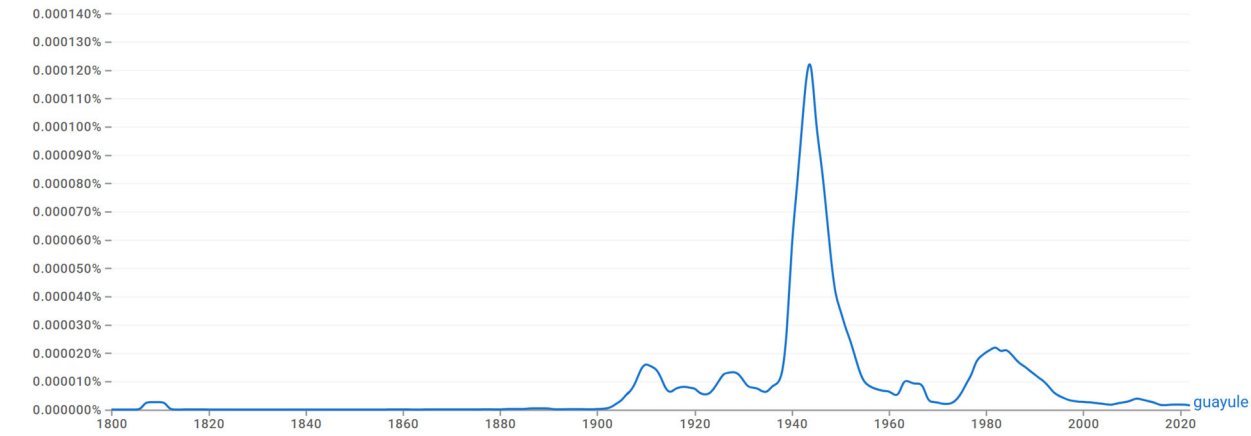
After Singapore was overrun, the U.S. government had second thoughts about guayule, and three weeks later Congress passed the Emergency Rubber Act (5 March, 1942), sometimes known as the Guayule Act. The legislation appropriated $45 million, and authorized buyout of the IRC facilities, intellectual

property, and acreage in Salinas, and a total of 50,000 acres in guayule on government owned or leased land, an authorization increased in panic to 500,000 acres in October 1942, following the release of the Baruch (Rubber Survey) Committee report. This would permit an estimated annual harvest of 80,000 LT a year.

These numbers are close to those that would have resulted from implementation of the Eisenhower plan. But it was too late. Guayule plants take four years to mature. Farmers pressured into Emergency Rubber Project contracts to grow guayule soon wanted out, so they could grow more profitable cash crops. Most of the acreage planted was eventually plowed under before it could yield much rubber.[47]

Thomas Edison, who spent the last four years of his life researching plant-based alternatives to *hevea*, was never a fan of guayule as an emergency rubber source for the same reason: the plant took too long to reach maturity.[48] Had some version of Eisenhower's plan been implemented earlier, however, mature plants would have been available for harvesting well before 1942.

Figure 2: References to "Guayule" in English Language Texts, 1800-2023



[47] U.S. Department of Agriculture, *Emergency Rubber Project: A Report on our Wartime Guayule Rubber Project* (Los Angeles, 1946)
[48] Finlay, *Growing American Rubber,* ch. 3.

Note: The plot displays, by year, the frequency of ngrams (in this case a 1gram) in a corpus of printed works in English, in other words, what fraction of 1grams match the identified text string. The option of searching independently of case (case-insensitive) has been selected, and the annual data are smoothed (smoothing parameter = 2).

A Google n-gram search reveals how serious was interest in guayule during the war. The initial peak in 1910 corresponds with the success of the activities of the Intercontinental Rubber Corporation prior to the shutdown of facilities due to revolutionary activity in Mexico. The increased frequency of references in the 1920s corresponds exactly with the success of the Stevenson plan in jacking up the world price of natural rubber, and the decline of references in the first half of the 1930s with the Depression era collapse in its price. The spike in references during the war peaks in 1943, the year of maximum U.S. military production. (The 1980s boomlet reflects the discovery that items made from guayule, such as disposable gloves, could be a viable alternative for those allergic to latex).

Synthetic Rubber

In 1939, when war broke out in Europe, it was not too late for stockpiling but almost too late for guayule. By March 1942 it was too late for either. The two counterfactuals discussed above are no longer relevant, because the contemplated actions were no longer possible. A synthetic rubber program was now unavoidable if the country was to prosecute the war successfully. Such a program was under discussion by the Army-Navy Munitions Board beginning in early 1939. Representatives of Standard Oil (NJ) met with the Board repeatedly during that year, and sketched out a program that, with some modifications, reflected the design ultimately embarked upon.[49] The design and execution of that program has, like so much about the U.S. economic mobilization effort, been uncritically lionized.[50] The underlying chemistry was well understood, but there was limited experience with the processes that stood at the center of Standard's blueprint, which relied exclusively on petroleum as the source for butadiene.

There was consensus ex ante that the risks of war with Japan were high, and, conditional on a state of war, that the probability of losing access to Southeast Asian rubber was even higher. When examined

[49] For details, see testimony of F. A. Farish, President of Standard Oil (N.J.) to the Truman Committee (U.S. Senate, *Hearings*, p. 4396).
[50] American Chemical Society, "United States Synthetic Rubber Program, 1939-1945" (1998).

from the perspective of national security, two synthetic rubber program decisions look questionable both in prospect and in retrospect.

The first was to design the program heavily around the use of petroleum rather than alcohol as the precursor for the butadiene that would be copolymerized with styrene to make GR-S. Butadiene had no other commercial uses so there was little experience manufacturing it and no option of diverting existing production flows from less essential uses. The second is the more than a full year delay in beginning to build the butadiene plants after the basic design of the program had been set in November 1940. Supplying butadiene in large quantities was widely understood to be the most problematic part of the synthetic program, of far more concern than the copolymerization plants. At the time of Pearl Harbor, construction had begun on none of the butadiene plants.[51]

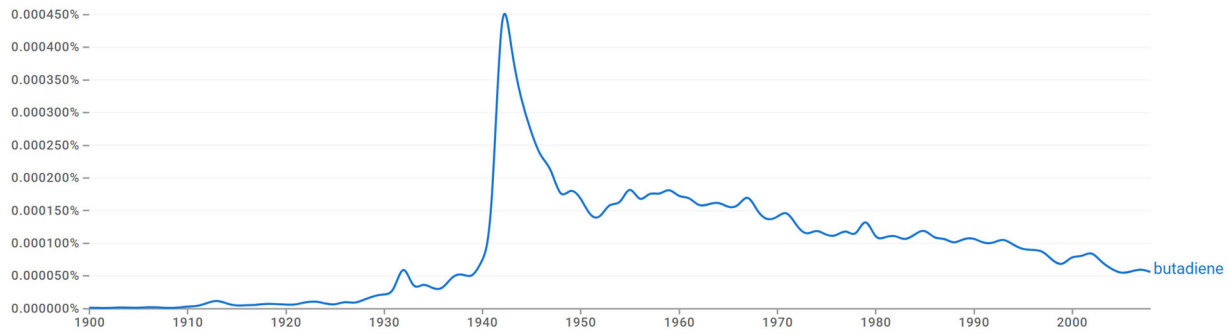
The design of Standard's initiative was heavily influenced by the commercial interests of oil companies, particularly Standard, in having the government lay the foundations for a synthetic rubber program that might or might not be profitable in the postwar period, but if it were, would provide a market for byproducts of crude oil refining. The emphasis on petroleum as the exclusive precursor for butadiene reflected that interest, but it did so at the cost of jeopardizing the national (and Allied) objective of winning the war. The design decisions, in the event, did not cause the war to be lost, but they made the economic situation more precarious than it needed to be, even after March 1942, when the necessity of some synthetic rubber program became a given. This in turn constrained the ability of the United States and its allies to project force, especially in 1943.[52]

Goodrich and Goodyear had experimented with synthetic rubber before the war, trademarking their products as Ameripol and Chemigum respectively. Standard viewed these as versions of Buna-N – a

[51]Solo, *Synthetic Rubber*, p. 24. In September 1941, Rubber Reserve (in other words, Jones) ordered Standard Oil to stop engineering work on a planned government funded butadiene plant in Baton Rouge, LA. This is another instance of Jones's efforts to delay or stop the development of a synthetic rubber program. Standard continued the engineering design at its own expense (Farish testimony, U.S. Senate, *Hearings*, p. 4465).
[52]Solo, *Synthetic Rubber*, pp. 80-82.

synthetic based on the copolymerization of butadiene with acrylonitrile rather than styrene.[53] Standard claimed that, through its patent exchange agreements with IG Farben, it had U.S. rights to this product, as well as GR-S – the U.S. nomenclature for what the Germans called Buna-S. Through legal pressure prior to Pearl Harbor Standard forced a wartime standardization on GR-S, a general-purpose rubber suitable for tire treads and carcasses. To make GR-S, one needed styrene, which was manufactured commercially, and butadiene, which was not.

Figure 3: Frequency of References to "Butadiene" in English Language Texts, 1900-2020



Note: The plot displays, by year, the frequency of ngrams (in this case a 1gram) in a corpus of printed works in English, in other words, what fraction of 1grams match the identified text string. The option of searching independently of case (case-insensitive) has been selected. The annual data have not been smoothed.

Butadiene, a gas, could be obtained in multiple ways. The process preferred by Standard worked from isobutylene, a byproduct of its oil refineries. It could also be made from butane, or from naphtha, both of which could also be byproducts of the distillation and refinement of crude oil, depending upon how the crude oil was cracked. Butane is also abundant in natural gas. And finally, butadiene could be produced from industrial alcohol (ethanol) which could be obtained either from fermentation of plant material or

[53] Aside from styrene and acrylonitrile, no other copolymers for butadiene have been found suitable for making synthetic rubber.

synthesized from petroleum.[54] The butadiene would then be copolymerized with styrene in a 3:1 ratio to make GR-S.

Neither copolymerization nor additional manufacture of styrene was anticipated to pose serious problems, and they did not. The big question was butadiene, particularly because the process favored by Standard was untested. Yet the original design of the program was built entirely around the use of petroleum rather than ethanol as feedstock. Once the program had been designed along this route, and in the absence of an alternative, its execution was delayed, and once again, Jones' skepticism about the severity of the threat played a role.

Table 1

Timeline of the Synthetic Rubber Program in the United States

1- Jan-1939 Representatives of Standard Oil New Jersey (SONJ) begin meetings and correspondence with the Army Navy Munitions Board (ANMB) (U.S. Senate 1942, pp. 4384, 4396).

9-Oct-1939 SONJ reps meet with ANMB, argue that synthetic industry capable of producing general-purpose rubber essential for U.S. national security. SONJ prepared, with government support, to lead effort to create one (Solo 1959, p. 6).

19-Nov-1939 SONJ meets again with ANMB, describes "cooperative plan" to develop synthetic rubber: Big 4 rubber companies along with Standard would developing copolymerization plant; Standard to supply the butadiene. Standard wants subsidy or guaranteed buyer for synthetic rubber products. ANMB says no to government funds, but would provide letter of support, giving SONJ some protection against antitrust prosecution.

Jan-1940 Full plan presented; discarded three months later because of fears of antitrust challenge. SONJ then proposes cross licensing scheme between rubber companies and Standard in which royalties to be shared by all parties with most going to SONJ. Plan discarded in April due to fears of antitrust challenge.

28-May-1940 National Defense Advisory Committee (NDAC) established. Edward R. Stettinius Jr. head of its Raw Materials Division, assisted by William Batt, forms Francis Committee to develop rubber policy.

1- Jul-1940 Francis committee recommends synthetic rubber program capable of producing 100,000LT/yr. Number obtained by polling companies, asking how much they would be interested in producing.

7-Aug-1940 Ten manufacturers meet with NDAC, agree to draft engineering plans to provide 108,000LT of GR-S (Buna S).

12-Sep-1940 After ANMB approves proposal, and recommends $50M for plants, letter from Stettinius to FDR outlines severity of threat of rubber cutoff, emphasizes lead times of 18 months to build plants.

[54] On the hydrocarbon chemistry involved in the different routes to producing synthetics, as well as data on the relative productivity of the petroleum and ethanol-based butadiene plants, see Field, *Economic Mobilization*, ch. 3.

Sep-1940 Stettinius and Batt approach Jones to discuss funding, based on their letter to the President. Batt testifies in 1942 there was "difference of opinion" between Stettinius and Batt, on the one hand, and Jones; Jones found their proposal "reckless". Jones testified that he was skeptical of need for (that) much synthetic capacity, that the President shared his view, and if there was to be federal support, the oil and rubber companies should deal directly with Jones. (U.S. Senate 1942, pp. 4285, 4287).

25-Nov-1940 Stettinius memorializes that, given the "unsatisfactory" earlier meeting, responsibility for synthetic rubber had, at Jones' request, been transferred from NDAC to RFC. Also notes that "There has been some question raised as to the speed with which the arrangements for the production of synthetic rubber are progressing" (U.S. Senate 1942, p. 4358).

Nov-1940 NDAC proposal for a 100,000LT program is formally submitted to Jones. Jones rejects it, instead asking what might be done with $25 million, which would fund perhaps 40,000LT program.

15-Jan-1941 SONJ proposes to build a plant to produce butadiene from oil, financed 75 percent by RFC, 25 percent by Standard. "Nothing came of this proposal" (U.S. Senate 1942, p. 4463).

Jan-1941 Roosevelt replaces NDAC with the Office of Production Management (OPM).

February 1941 Jones cancels entire synthetic rubber program.

28-Mar-1941 In response to protests, the RFC proposes Big 4 rubber product companies each build 2,500 ton (annual) capacity copolymerization plant for demonstration purposes. No provision for construction of butadiene plants.

9-May-1941 William Knudsen (Director of OPM) writes to Jones telling him (ordering him?) to proceed with 40,000LT program, saying that might ultimately be increased to 100,000 or 200,000LT. Jones agrees to 40,000LT program. In that month Jones allows contract authorizations for 15,000LTs of butadiene capacity but does nothing more on butadiene until after Pearl Harbor.

16-Sep-1941 Jones, working through Stanley Crossland at the RFC, orders SONJ to cease engineering work on a planned government funded butadiene plant in Baton Rouge. SONJ continues planning at its own expense. W. A. Farish, President of SONJ, testified in 1942 that he did not know reason for cancellation. At the same hearings Jones testified cancellation ordered because "we found we could buy the raw material without building the plant, that we didn't need the plant." No details offered on the mystery source (U.S. Senate 1942, pp. 4478, 4540, 4621).

7 Dec- 1941 Pearl Harbor attacked.

2-Jan-1942 War Production Board (WPB) created, supplants OPM.

7-Jan-1942 WPB orders whiskey distilling industry to shift 60 percent of capacity to production of industrial alcohol.

12-Jan-1942 WPB announces target of 400,000LT/yr synthetic rubber program.

3-Mar-1942 WPB increases program to 600,000LT/yr GR-S, almost all butadiene from petroleum; 40,000LT from alcohol, most of the alcohol synthetically produced from petroleum.

Mar-1942 Gillette Committee hearings begin. Agricultural interests and farm state senators press to shift from petroleum to plant-based ethanol (alcohol) as the butadiene precursor.

21-Apr-1942 WPB, panicked, increases synthetic target to 800,000LT/yr.

24-May-1942 WPB raises alcohol portion of GR-S to 220,000LT/yr, at expense of planned butane to butadiene plants, due to previously overlooked alcohol distilling capacity.

22-Jul-1942 Rubber Supply Act passed by both houses of Congress; calls for synthetic rubber from alcohol produced from "agricultural or forest products."

6-Aug-1942t, 1942 Roosevelt vetoes Rubber Supply Act, sets up Rubber Survey (Baruch) Committee.

September 1942 Baruch Committee recommends GR-S target of 845,000LT/yr capacity, appointment of rubber 'czar', nationwide gas rationing, 35 MPH speed limit.

26-Sep-1942 Jeffers (rubber 'czar'), imposes 35 MPH nationwide speed limit, based on study showing tires last four times longer than at 65 MPH (Flamm 2006, p. 79).

26 Dec-1942 Roosevelt imposes nationwide gas rationing to save rubber, effective 1 December.

Feb-1943 First alcohol butadiene plant online. Capacity: 80,000LT/yr. Output through 6/1944: 151,190LT.

Apr-1943 First petroleum butadiene plant online. Capacity: 30,000LT/yr. Output through 6/1944: 22,210LT.

May-1943 Second petroleum butadiene plant online. Capacity: 15,000LT/yr. Output through 6/1944: 20,600LT.

July-1943 Second alcohol butadiene plant online. Capacity: 80,000LT/yr. Output through 6/1944: 95,380LT.

Aug-1943 Third alcohol butadiene plant online. Capacity: 60,000LT/yr. Output through 6/1944: 74,800LT.

Feb-1944 Third petroleum butadiene plant online. Capacity: 100,000 LT/yrs. Output through 6/1944: 18,180LT.

Apr-1944 Fourth petroleum butadiene plant online. Capacity: 50,000LT/yr. Output through 6/1944: 3,580LT.

Aug-1944 Fifth petroleum butadiene plant online. Capacity: 55,000LT/yr.

Sources: 1939-42: U.S. Senate, *Hearings;* Solo, *Synthetic rubber*; 1943-44: U.S. War Production Board, *Special report of Office of the Rubber Director,* Table II, p. 4; Wendt, 'Control', p. 209.

The first part of Table 1 documents the impact of Jones and the RFC in delaying the construction of plants to produce butadiene and in general acting to block or slow the development of a synthetic rubber program, until overruled by William Knudsen at the Office of Production Management. We also see the frantic increases in the targeted size of the program starting in early 1942, as the full scope of the looming disaster became apparent. The timeline also documents the belated willingness, under the WPB, to allow some of the butadiene production to come from plants using ethanol. The first butadiene plant was not completed until April 1943. All three of the big alcohol plants opened that year, and they produced far more than their rated annual capacity. Of the five petroleum-based butadiene plants, the three largest did not begin production until 1944, and consistently produced below their rated capacity.

Of the total 425,360LT of butadiene produced up through and including June 1944, the month of the D-Day invasion, 321,370LT was produced by the alcohol-based plants. The four butylene-based petroleum plants listed on the timeline provided just 64,570LT.[55]

A Third Counterfactual

Given earlier inaction or inadequate action on stockpiling or guayule, the delays in butadiene production were one of a number of factors (shortage of landing craft was another) making near impossible the execution of a successful cross channel invasion in 1943, as originally planned.[56] U.S. rubber consumption (all sources) fell from 781,258LT in 1941 to 394,442LT in 1942 before rising to 488,525LT in 1943 and then 710,783LT in 1944. Assume that the difference between 1944 and 1943 consumption (222,258LT) roughly represents the additional requirements of a cross-channel invasion counterfactually moved back in time by one year, and that Lend Lease continued at actual 1943 levels, as did military action in the Mediterranean/Italy, China/Burma, and Pacific theatres. The natural rubber stockpile had already fallen to 139,594LT by the end of 1943. The country could not have squeezed more natural rubber imports from Africa and Latin America in 1943 or it would have done so, and the same was true of synthetic production, given Jesse Jones' earlier obstructionism. Even if the 1943 end of year stockpile had been entirely depleted in support of an earlier cross channel invasion, there remains a gap of 82,644LT, or about a third of the delta, for which no alternate sources in 1943 can be identified. As it was, in 1944 the military was forced to strip tires from domestic motor pools and ship them to Europe and take delivery of vehicles without spares and in some cases without tires.[57]

[55] U.S. War Production Board, *Special Report of Office of the Rubber Director on the Synthetic Rubber Program: Plant Investment and Production Costs*. (Washington, D.C., 31 August, 1944), Table II, p. 4.
[56] Contrary to Wendt, the November 1945 statement by the WPB Director of Rubber Programs that "Broadly speaking, no vehicle, military or civilian, stood still for lack of tires, and no military operation was delayed because rubber equipment was lacking" should be questioned (Wendt, 1947, p. 225). In discussing the rubber shortage, Koistinen concluded that postponing the invasion "saved the nation from disaster" (Koistinen, 2004, p. 157).
[57] U.S. Army Service Forces, *Annual Report of the Director* (Washington, 1945), p. 199.

Without alcohol-based butadiene, it's hard to see how D-Day could have gone forward in June 1944. In retrospect, it's not clear that petroleum-based butadiene was needed at all to win the war. Butadiene from isobutylene was cheaper in the long run because, even though plants using this input were more expensive to construct, required more complex engineering, and relied on untested processes, the feedstock (petroleum) was ultimately cheaper. Due to huge agricultural surpluses accumulated during the Depression, however, the opportunity cost of ethanol was far lower during the war years, an advantage augmented by the much lower capital requirements of the process using it to produce butadiene.

The U.S. government ended up establishing the foundations for a commercially successful synthetic rubber industry in the postwar period, one using petroleum as the principal feedstock, as Standard intended. Given that synthetic rubber would be needed during the war, it would have been cheaper and faster to have focused from the outset on ethanol as the feedstock. Standard Oil bears responsibility for the emphasis on petroleum. Whether petroleum or ethanol was to be the feedstock, however, construction on the butadiene plants should have started earlier, and for that, Jones bears much of the responsibility.

The Economic Effects of the Rubber Famine

The rubber famine's negative impact on productivity (efficiency) operated through multiple channels, both within the manufacture of rubber products and in the expanding industry producing synthetics. Synthetic rubber (GR-S) was an imperfect substitute for natural, lacking its plasticity and tack. When flexed and allowed to return to its original shape it generates more heat than natural.[58] The manufacture of almost all products required blending synthetic with natural, or in some cases, especially airplane and heavy truck tires, could use no synthetic at all, which is why the supplies of natural rubber remained so critical.[59] In the final stage of fabrication (where natural and synthetic was blended along with additives

[58] Whaley, "Western Hemisphere," pp. 18, 28.
[59] The Germans entered the war with an advanced synthetic rubber industry using brown coal as the feedstock for butadiene to make Buna-S. But, as did the United States, they faced the same challenge of obtaining adequate supplies of natural rubber. They relied on their own stockpile, seized French stockpiles, and, prior to 22 June, 1941, shipments of Southeast Asian rubber from its ally Japan via the Trans-Siberian railroad. After June 1941 such

and fillers and then vulcanized), mixtures of synthetic and natural rubber took longer to mill and required up to a third more labor time as compared with all natural.[60] The Baruch report noted this, and as a consequence anticipated a shortage of milling capacity in 1943 and 1944, which is precisely what happened. The constraint began to bind in January 1944 and continued through August, placing a hard cap on the total amount of rubber, synthetic and natural, that could be processed into final products. In the remainder of 1944, shortages of labor limited rubber product manufacture, as did a critical shortage of carbon black in the first half of 1945 that forced a cutback from seven to six days of weekly production.[61] Any uptick in production intermittency reduced total factor productivity by reducing capital productivity, since the capital service flows continued mostly uninterrupted, independently of the intensity of utilization.[62]

Even after the changes made in 1942, the design of the synthetic program heavily favored petroleum as the feedstock for butadiene. Priority claims on boilers, valves, pumps, heat exchangers, metals (particularly stainless steel, which needed chromium and nickel to manufacture), and other construction material and manpower were far in excess of what would have been necessary had alcohol played a more prominent role in program design.

In most cases the rubber program had priority access to subassemblies and materials, a preference which the Petroleum Administrator for War (Harold Ickes) bitterly resented and sometimes overcame.[63] The

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shipments came by sea which meant a more unreliable supply due to Allied naval interference. To address the vulnerability, and with only very limited success, Himmler tried, using forced labor in conquered eastern territories, to obtain natural rubber by cultivating the Russian dandelion (kok-saghyz), which had a 22 percent rubber content. William G. Clarence-Smith, "Synthetic and Temperate Rubber in the Interwar Years and during the Second World War," *Journal of Global History* 5 (2010), p. 173; Susanne Heim, *Plant Breeding and Agrarian Research in Kaiser-Wilhelm Institutes, 1933-1945: Calories, Caoutchouc, Careers (*New York, 2008).

[60] Wendt ("Control," p. 222) suggests that the milling penalty for working with blended GR-S/natural might be as low as 10 percent. This is probably based on the supposedly expert technical advice given to the Rubber Survey Committee in 1942 that just 10 percent of total rubber requirements for final products would need to be natural, so little mixing would be needed. The forecast was overly optimistic. At the end of the war, the actual percentage was about 30 percent, and for truck and airplane tires it was 100 percent (Solo, *Synthetic Rubber*, p. 84). After the war, according to Solo, it was 40 percent. See also B. S. Garvey, "Synthetic Rubber," *The Scientific Monthly* 52 (1941), p. 51) on the milling penalty associated with both Buna S and Buna N.

[61] Wendt, "Control," pp. 222-3.

[62] Field, *Economic Mobilization*, ch. 2.

[63] Wendt, "Control," p. 212.

more timely completion of the alcohol based plants reflected the reality that capital requirements were lower and the engineering less complex, placing less strain on supplies of construction materials, subassemblies, and specialized materials. Conflict with the aviation fuel program also probably played a role in prioritizing delivery of the more limited capital requirements for the alcohol plants and delaying completion of the petroleum-based butadiene plants. Isobutylene from refinery operations could be used to make either butadiene or toluene. The aviation program needed toluene to make 100 octane fuel, which permitted the operation of high compression engines.

If, by privileging petroleum as the feedstock, the rubber program obtained materials or construction labor it could have done without, it starved other sectors of scarce inputs. If it failed to get the inputs it needed, conditional on the design of the program, synthetic rubber supplies were delayed. In either case the result contributed to output intermittency, an affliction that dragged down productivity and product completion rates throughout the war. The rubber famine led directly to the imposition of a 35-mph speed limit and nationwide gas rationing in a country which, in the aggregate, was awash in petroleum. The intent was not to save fuel but to reduce tread wear on the tires installed on the nation's 27 million automobiles and 5 million trucks, almost all of which were otherwise forecast to be off the roads within two years.[64] These restrictions made it more difficult for people to get to work, contributing to absenteeism, and impacted the distribution of products by truck.

Prior to the war the country enjoyed cheap and reliable delivery of hundreds of thousands of tons annually of Southeast Asian natural rubber. In response to the cutoff, the production of synthetic required building 51 plants at a cost of about $700,000,000 and spending millions more to operate them. Synthetic rubber yielded, at great expense, an imperfect substitute for natural that required additional labor in final product fabrication.

[64] U.S. Special Committee to Study the Rubber Situation, *Report of the Rubber Survey Committee* (Washington, DC, 1942), p. 5.

The Rubber Survey Report (September 1942) repeatedly stressed the severe threat posed by the rubber famine. It emphasized how critical the availability of synthetic rubber would be in 1943, and planned/promised 400,000LT of GR-S. Because of the delayed completion and poor initial performance of the petroleum-based butadiene plants, less than half that amount was delivered. The Soviet victories at Stalingrad and Kursk gave the Allies breathing space, allowing delay of the cross-channel invasion, which irked the Soviets but was welcomed by the British. In the event, as noted, rubber shortages that year probably made a successful cross channel invasion impossible. During the following year (1944) synthetic production began to approach the expanded GR-S targets set during the panicked months of 1942. Now the complementarity between natural and synthetic began to bind, and as the natural rubber stockpile shrank to dangerously low levels, unusable stocks of synthetic accumulated.

Conclusion

The blue ribbon committee appointed by Roosevelt to survey the rubber situation did not mince words in its September 1942 report: "If we fail to secure quickly a large new rubber supply, our war effort and domestic economy will collapse."[65] In May 1942 Ferdinand Eberstadt had used similar language in a letter he wrote to Bernard Baruch: "unless synthetic rubber is available in quantity by the time the crude stockpile is exhausted… we would appear to have no alternative but to call the whole thing off."[66] There are no qualifiers here, nor reason to believe that the language was hyperbolic, nor reason, with the benefit of hindsight, to doubt their judgment.[67]

The magnitude of the threat to the United States may nevertheless still strike some readers as difficult to credit. A celebratory imperative emerging out of the evident victory of the United States and its allies has

[65] U.S. Special Committee to Study the Rubber Situation, *Report*, p. 23. The committee was composed of Baruch and the presidents of Harvard and MIT, James Conant and Karl Compton.
[66] Quoted in Tuttle, "The Synthetic Rubber "Mess," p. 38. See also John Colyer, "The Crisis in Rubber," *Science* 97 (8 Jan. 1943), pp. 32-36; p. 35.
[67] A pamphlet produced by B. F. Goodrich described the efforts to ramp up synthetic production as "a grim race against time for upon its successful solution depends the fate of all the United Nations." *Crisis in Rubber* (Akron, OH, 1943), Forward.

dulled our critical sensibilities in thinking about the economic history of the war, and this aspect of it is no exception. The rubber famine has largely faded from U.S. consciousness, and many are not aware that it really was a very serious thing.[68] For those who know more of the history, skepticism persists because of two related beliefs, both false: first, that the synthetic rubber program was almost effortlessly willed into existence -- the terms miracle and miraculous often feature in discussions of it -- and second, that once it was available, synthetic was an almost perfect substitute for natural. Synthetic rubber had to be blended with natural in the manufacture of almost all products – imposing a time and labor cost milling penalty – and for some products like airplane tires, only natural could be used.

By 1944 GR-S was finally available in quantity, but at that point the rapidly dwindling stockpile of natural rubber become the binding constraint on overall rubber product manufacture.[69] The frantic increases during 1942 in GR-S program targets combined with the reliance on petroleum-based butadiene and the delays in building the plants to produce the gas led to a program that underdelivered in 1943 and, in terms of the absorptive capacity of the economy, overdelivered in 1944. In the process of overbuilding capacity using an unnecessarily expensive process, the program sat on or consumed valuable resources needed by other war programs.

The 1944 report of the Rubber Development Corporation emphasized that the increased availability of synthetic in that year did not by any means alleviate the rubber famine: "the need for natural rubber under these circumstances remains as acute as ever, and every effort must be continued to assure that every possible ton will be secured from the sources available to us." In 1945 the War Production Board forecast

[68] For those still doubtful, see British journalist Alistair Cooke's observations on the U.S. rubber shortage during a 1941-42 cross country trip. Cooke, *The American Home Front* (New York, 2006), pp. 26, 60, 97-98, 125-26, 146, and 156.

[69] Shortages of carbon black, cotton and rayon fiber, milling capacity, and labor also contributed to difficulties meeting 1944 production targets. The appointment of Jeffers, the "rubber czar" recommended by the Baruch report, probably advanced the arrival of large quantities of GR-S by the latter part of 1943. But it also reduced the coordination within the WPB necessary to assure the availability of complementary inputs (Wendt, "Control," pp. 221-25).

that in the event of an invasion of Japan, the U.S. would simply run out of natural rubber in 1946.[70] Among other consequences, the U.S. would then have been unable to manufacture airplane tires.

Controls on the consumption of natural (but not synthetic) rubber continued after VJ day.[71] The frenzied buying and stockpiling of natural rubber by the United States at the outbreak of the Korean War offers additional testimony to the imperfect substitutability of synthetic for natural rubber and underlies again how critical was the size of the natural rubber stockpile in 1942. At the start of the Korean conflict, the Preparedness Subcommittee of the Senate Committee on Armed Forces, chaired by Lyndon Baines Johnson, announced that "we must stockpile and conserve rubber as if our very lives depended upon it because that may be the reality."[72] Johnson made this statement even though the U.S. government then possessed a large synthetic capability, with abundant access to the necessary feedstocks, all still entirely under its own control.

Taking a broader view, the history of rubber before and during the war highlights the benefits and risks for the United States of reliance on global supply chains, particularly for materials of strategic importance. The basic tradeoff – one evident during the pandemic in choices involving vaccine manufacturing supplies and personal protective equipment and immediately after it in the supply shortages due to scarce computer chips -- was between the risks of depending on cheap foreign sourcing that might not always be available and the expense and efficiency penalties of stockpiling or developing or retaining standby or operational raw material or manufacturing capacity via subsidies or protection.[73]

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[70] U.S. Rubber Development Corporation, *Report of the Operations of Rubber Development Corporation, February 23, 1943 to August 31, 1944* (Washington DC, 1944), p. 22; U.S. War Production Board, *Wartime Production Achievements*, p. 94.
[71] Wendt, "Control," p. 218.
[72] William R. Langdon, "Malaya's Rubber and Tin," *Current History* **23** (1952), p. 146.
[73]The dilemma remains with us today, not just generally, *but also specifically with respect to natural rubber*. A 2024 MITRE Corporation report to the Department of Homeland Security underscored the reality that eight decades after the end of World War II, the United States is still vulnerable to cutoff of Southeast Asian supplies. The threat now comes from China, not Japan, but the key reason remains that synthetic rubber cannot be used for products where heat buildup is an issue, especially airplane or heavy truck tires. The report advised that "To address this vulnerability, the U.S. should consider creating a national stockpile of natural rubber. It should also significantly increase federal research into alternative sources of natural rubber, including synthetic rubber." These words might

In April 2025 the United States experienced some of the most incohrerent economic policy making in modern economic history. Among its many defects, President Trump's rollout of threatened 'reciprocal' tariffs featured rates calculated according to a method apparently uninformed by a an understanding of basic balance of payments accounting. It is against this standard that Jesse Jones' role in aggravating the World War II rubber famine may be considered. To his credit, there is no evidence that Jones or anyone close to him benefitted financially from his stances. And, following Pearl Harbor and the fall of Singapore, he worked effectively to implement a flawed program. Still, he slowed or stood athwart implementation of two of the three risk mitigation strategies (stockpiling and synthetic rubber) and would have done so for the third (guayule), had it been within his bailiwick. The consequences for U.S. productivity and the ability of the country to prevail in the war were serious.

In general, a country benefits from civil servants who are honest and effective. But it also needs those who can recognize when they need to seek out additional knowledge or expertise. Roosevelt, though he appears initially to have shared some of Jones' gut level judgements and prejudices, eventually realized this, and, in the summer of 1942, availed himself of the counsel of Baruch, Conant, and Compton. By then, considerable damage had already been done. The time window during which two of the three key mitigation strategies (stockpiling and guayule) could have been exploited had closed. And the implementation of the third (synthetic rubber) had, beyond its design defects, been seriously delayed.

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easily have been written in 1939. MITRE Corporation, "Is Natural Rubber the Next Critical Material to Challenge the U.S. Economy? An Evaluation of Threats to Supply." Report for the U.S. Department of Homeland Security, dated June 24, 2024, p. iii.

In September 1942 the distinguished American journalist Mark Sullivan wrote that "Our deprivation of rubber is as great a disaster … as Pearl Harbor." Unlike the latter, however, he attributed the former to "our own unforgivable negligence, prolonged over many months."[74]

U.S. vulnerability to rubber cutoff during the war was inescapable. Both before and after U.S. entry, that vulnerability could have been addressed in ways that would have required different or more spending in advance, but, ex post, been far less damaging to wartime productivity and national security. As in all considerations of insurance, such spending might, after the fact, have been deemed unnecessary, using the same questionable logic that might lead one to argue that house insurance last year was a waste because, in its absence, one would be richer (assuming the house hadn't burned down). In the rubber case, additional and/or different ex ante expenditures would have been well justified by reasonable estimates of the risks they would have been intended to mitigate.

[74] Mark Sullivan, "Our Negligence: The Sad Saga of Rubber." *Washington Post*, 14 September, 1942. A yellowed copy of this and other critical columns, along with others aimed at exonerating him, can be found in Box 203 of the Jesse Jones papers in the Library of Congress.