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WHY LIBERAL COSMOPOLITANS SHOULD WORRY ABOUT SUPPLY CHAINS

By Tyler Cowen*

Abstract: *The complexity of supply chains means that it is difficult to tell where national security arguments begin and end. That may weaken some of the traditional arguments for free trade for the same reasons that we accept the difficulty of rational economic calculation in a socialist society. National security arguments for protectionism may not remain restricted to very small and manageable segments of the economy. Liberals and cosmopolitans will need to pay greater heed to these problems. This essay also considers why complex supply chains may create problems for a carbon tax and for the notion of corporate social responsibility.*

KEY WORDS: supply chains, economic coordination, national security, socialist calculation debate

I. Introduction and the Central Problems of Complementarity and Knowledge

There is general agreement among economists about free trade. In most cases, free trade enhances economic efficiency, albeit with distributional consequences. It is also recognized that national security arguments provide a possible exception to free trade doctrine. We can agree on those propositions, but I wish to suggest also that liberal cosmopolitans need to worry about supply chains much more than that baseline understanding would suggest. As we will see, the key problem is that the robustness of supply chains is undersupplied.[1]

As long ago as 1776, Adam Smith recognized the national security exception to the free trade argument; he has hardly been defrocked for his deficient understanding of markets. For Smith, one relevant national security consideration was shipping. Smith favored the seventeenth-century mercantilist Navigation Acts in part because they would enable Britain to maintain and extend its shipping capacities and its navy.

To consider a more recent example, high-quality semiconductor chips are essential to build top-notch military equipment; furthermore, they keep the

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[1] For one look at recent work in this area, see Bomin Jiang, Daniel E. Rigobon, and Roberto Rigobon, "From Just in Time, to Just in Case, to Just in Worst-Case: Simple Models of a Global Supply Chain Under Uncertain Aggregate Shocks" (National Bureau of Economic Research Working Paper No. 29345, October 2021). Management research is in the lead here; for instance, see recent research publications in the *Journal of Supply Chain Management.*

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United States technology sector up and running. Yet most of those chips are produced in Taiwan as well as South Korea. Both of those countries are very close to China and potentially vulnerable to military disruption in case of conflict. There is thus a current push for the United States government to subsidize domestic semiconductor chip factories. That likely would involve higher costs, but it would strengthen national security and guarantee chip access in critical times. As I will discuss in more detail below, a number of critical supply issues also came to the fore during the COVID-19 pandemic.

These problems are more than just "one-offs," as the growth of globalization and international trade makes the world increasingly interdependent, and hence supply chains more complex. We are familiar with benefits from those developments, but there is also a cost. The more complex the supply chain, the more difficult it may be to draw sharp distinctions between "goods essential to national security" and "goods not essential to national security." If your domestic economy is not sufficiently robust, perhaps your national security is not robust either. Where exactly do national security supply chain problems begin and end?

The remainder of this essay will proceed as follows. Section II outlines the main supply chain problems in more detail, focusing on their conceptual underpinnings and relating them to earlier arguments about the difficulty of economic calculation under socialism. Section III addresses a worry about the extent to which national security arguments might reach into economic policy. Section IV considers whether economies are moving more in the direction of substitutes or complements, a key question for understanding the extent of supply chain failures and sometimes how to fix them. Section V expands the basic arguments to questions of carbon taxation and corporate social responsibility. Section VI offers brief concluding remarks. My arguments relate to the central concern of how liberals and cosmopolitans should think about a world where national security issues are important and supply chains are increasingly complex.

II. Two Specific Problems: Complementarity and Knowledge

I will outline two key problems in this section, namely, complementarity and knowledge. First let us consider complementarity, namely, that some goods or inputs do not have ready substitutes.

Complementarity issues came to the fore with the COVID-19 pandemic. A pandemic is not literally a war, but often during pandemics some parts of international trade dry up. Early in the pandemic, the United States was short of high-quality masks and that made it difficult to run hospital emergency rooms in a sufficiently safe manner for medical personnel. The primary production locale for such items was China, which was having its own problems with COVID-19; for a while, China was not willing to export those masks (though many slipped out through black markets) or the exported masks did not work properly. All of a sudden, the

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United States and many other countries wished their domestic mask production capacities were better and that they had maintained their mask stockpiles better. This shortfall eventually was remedied, as U.S. mask factories were mobilized to make the desired products and Americans learned how to distinguish higher-quality from lower-quality Chinese products, but it likely cost lives in the meantime. Furthermore, there is the fear that without subsidies for domestic U.S. mask production, America will return to longer-term reliance on cheaper Chinese masks or from some other cheaper external market.[2]

The vaccines also reflect supply chain and national security issues. In this instance, the United States has been on the "long" side of the market, while many other countries wish they had developed higher domestic vaccine capacity. Such an outcome may not have been feasible for many poorer or smaller countries, but France in particular would seem to have the wealth and scientific and administrative capacity to produce domestic vaccines in a timely manner. Yet the actual French vaccine attempts were failures. France thus was relatively late accessing quality vaccines, unlike the United States or the United Kingdom, which both could access domestically produced vaccines. India, which has become a major vaccine-producing center, did better than other countries of comparable per capita income when it came to early vaccine access. Part of this story, however, is that India reneged on some of its commitments to export vaccines to other countries.

Note that for the United States, domestic vaccine production largely had fled the country for cost and regulatory reasons, but it was restored in part due to subsidies and liability protection signed into law by the Bush Administration in 2005. The stance of government policy really makes a difference.[3]

Advanced vaccines are in any case internationalized products. A Moderna mRNA vaccine involves components from Spain, the Netherlands, France, South Korea, and Switzerland, at a bare minimum. Pfizer drew upon technologies and components from Canada, the United Kingdom, Germany, Belgium, and other nations. Are those components also covered by national security arguments? What about the components behind those components? While substitution in production often is possible, it can lead to delays and thus more deaths during a pandemic. In some cases, substitution in production may be difficult, as illustrated by the lipid

[2] On mask issues, see Rana Foroohar, "Cheap Masks Carry a High Cost for US Manufacturing," *The Financial Times*, October 13, 2021; also see Paul L. Joskow, "From Scarcity to Abundance: Government and Private Initiatives to Manage the Allocation of N95 Masks in the U.S. During the COVID-19 Pandemic" (National Bureau of Economic Research Working Paper No. 29876, March 2022).

[3] See, e.g., Robert Roos, "Bush Asks $7.1 Billion to Prepare for Flu Pandemic," Center for Infectious Disease Research and Policy, November 1, 2005, https://www.cidrap.umn.edu/avian-influenza-bird-flu/bush-asks-71-billion-prepare-flu-pandemic.

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nanoparticles necessary for those vaccines or for the specialized filters required for the Pfizer vaccine. In other words, there seem to be some "cannot substitute away from" processes involved in production.[4]

Consider another example of highly specific inputs, namely, ASML Holding, a company based in Veldhoven, the Netherlands that manufactures a $150 million tool that "uses a different kind of light to define ultrasmall circuitry on chips." The tool took decades to develop and shipping it involves the mobilization of forty shipping containers, twenty trucks, and three Boeing 747s. The machinery is necessary to make the best semiconductor chips and only this one Dutch firm makes it. Furthermore, it is believed that it would take China more than a decade to develop its own capacity to make this item, even assuming it could reach similar quality levels. The company, ASML, is now worth about $285 billion (circa mid-2021) and it has been described as "the most important company you've never heard of."[5]

This particular input is more of a problem for the Chinese supply chain than the U.S. supply chain. In fact, there are Dutch restrictions on exporting the items to China, with those restrictions strongly backed by the United States. More broadly, the United States has a much closer working relationship with the Netherlands than does China. America also has a much stronger military presence in the Atlantic region, so it is likely to stand first in line before the Chinese for a long while to come, even if the export restrictions were loosened. In any case, lack of access to such devices is one reason why China has not developed world-class semiconductor chip manufacturing capabilities.[6]

Now let us consider another contributing factor, namely, knowledge problems. We do not always know which parts of supply chains may turn out to be crucial for national security.

In pandemic times we have seen supply chains scrambled in highly unusual and sometimes unexpected ways. In 2021, for instance, anecdotes of the "$700 a day rental car in Hawaii" were legion. Why such a price? Rental car companies sold off much of their fleets when travel collapsed in 2020. When they tried to replenish their fleets, they found that computer chip shortages were making new cars difficult to come by. The computer chip shortages, at least in part (but not only, with earthquakes and floods as additional issues), stemmed from pandemic-related supply problems. If you look at U.S. price inflation of 2021, used cars and rental cars played a significant role in the rise of that index. Were such developments obvious to

[4] On the Moderna and Pfizer supply chains, and on these supply chains more generally, see Chad P. Bown and Thomas J. Bollyky, "How COVID-19 Vaccine Supply Chains Emerged in the Midst of a Pandemic," *The World Economy* 45, no. 2 (2022): 468–522. The Novavax vaccine depends on a specialized adjuvant extract from the soap-bark tree of Chile.

[5] See Don Clark, "The Tech Cold War's 'Most Complicated Machine' That's Out of China's Reach," *The New York Times*, July 4, 2021.

[6] Clark, "The Tech Cold War's 'Most Complicated Machine.'"

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planners or policymakers in advance? Probably not. The pundits also were not forecasting this development.

A shortage of some kinds of medical gear was perhaps an obvious result from a pandemic, but how about the revenue collapse at U.S. hospitals? That one was more difficult to see coming, although ex post it seems obvious as so many prospective patients postponed their elective surgeries, which are typically high-margin services. Or was it easy to forecast the inability of Nike to pivot away from its "Just in Time" inventory approach to keep retail shelves stocked with its shoes?

As of the Fall of 2021, shortages were reported in the following areas: pipettes and petri dishes for medical labs, French fries at Burger King, fancy plastic bags used in labs, and a large variety of goods shipped either by truck or through ports. Again, there are nonobvious events on that list. Part of the problem was that the demand for consumer durables skyrocketed during the pandemic, as people stayed at home more. Ports and shipping containers could not handle those demands; at the same time, labor shortages came along in many economies. The result was not only shortages in many sectors of the economy, but shortages largely unexpected in their specifics.[7]

Until fairly well into 2020 it was not clear to many experts whether the mRNA vaccines would work at all. Circa December 2019, hardly anyone would have considered their components essential to U.S. national security. Even late into 2020, most nations were slow to order those vaccines for their citizenries, including such typically well-run countries as New Zealand and Australia.

As I write this in 2021–2022, the conflict in Ukraine is in its early stages. It remains to be seen which national security arguments will prove of most relevance, but both Ukraine and Russia rely on a large number of specialized components and specially trained labor to make their militaries work. The disruption of Ukraine also separates many poorer countries from their grain supplies, creating problems of malnutrition and hunger. As for Russia, cutting it off from international systems of payment and finance has damaged the economy significantly. Some individuals suggest that the unique vulnerability of the Russian military comes at the level of machine tools. I am not endorsing these claims, only noting that we cannot easily know in advance which ones will turn out to be most important.

The problem is this: If you think liberalism has to worry about supply chain issues, liberalism also has to worry about these epistemic issues. However, liberalism has a long-standing history of trying to tag central planning with those same epistemic headaches. In reality, those headaches are a problem for liberalism itself more than anticipated.

[7] See Matt Stoller, "America Faces Supply-Chain Disruption and Shortages. Here's Why," *The Guardian*, October 1, 2021; and David J. Lynch, "Covid Pandemic Is Not the Supply Chains' Only Problem," *The Washington Post*, September 30, 2021.

National security arguments thus intersect with socialist calculation arguments. Friedrich A. Hayek, in his "The Use of Knowledge in Society," argues that markets can work well by accessing the local information contained in prices.[8] Those prices could serve as sufficient statistics for what otherwise would be an unknowable or at least highly complex set of underlying supply and demand conditions. In Hayek's accompanying articles (and those of Ludwig von Mises) on socialist planning, he argues that it is impossible for anyone to access directly all of that underlying (price-aggregated) information.[9]

Hayek was on target, but notice one implication: The Hayekian dilemma also may apply to attempts to manage, regulate, or even understand complex supply chains. If individuals or governments do not know what is going on behind the scenes and have to rely on prices as sufficient statistics, how well can they understand the specifics of supply chains?

Let's make this more specific. In Hayek's classic supply chain example, if the price of tin goes up, a market economy still brings the appropriate reactions, even if few people know why that happened. People will economize on tin, seek out tin substitutes, and move away from production methods that require a lot of tin, all for the better.

Yet on the national security side, the argument is trickier. Fixing such national security problems would seem to require a direct understanding of how the supply chains work. As stated above, in wealthier, more complex economies it is more difficult to trace interconnections and we are all the more reliant on a market economy to transmit relevant information about scarcities in a decentralized manner. That will mean interdependencies are more important and at the same time less transparent. For the defense of Sparta, it may have been sufficient that enough men were trained to fight with bravery. The current United States, though, has so many complex pieces of the defense puzzle that it is difficult for observers to figure out what is important for national defense and what is not. Does the U.S. need high-quality semiconductor chips? Rare earths? Technologies for hypersonic weapons? An Iron Dome system? Defenses against bioweapons? What about all of the involved components?

I was surprised in May of 2022 to discover that American medical scans were in short supply because the requisite dyes to conduct those scans often come from China, particularly a GE Healthcare factory in Shanghai. Chinese workplace shutdowns, occasioned by early 2022 Covid problems, led to difficulty obtaining those dyes, thus causing many discretionary scans to be postponed. At the start of the pandemic, that was not an easily anticipated

[8] Friedrich A. Hayek, "The Use of Knowledge in Society," *American Economic Review* 35, no. 4 (1945): 519–30.

[9] See, e.g., Friedrich A. Hayek, "Socialist Calculation: The Competitive 'Solution,'" *Economica* 7, no. 26 (1940): 125–49; Ludwig von Mises, *Economic Calculation in the Socialist Commonwealth* (Auburn, AL: Ludwig von Mises Institute, 1990).

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outcome, including its timing two-and-a-half years after the pandemic began.[10]

A look at history also drives home how national security arguments may have applied to quite different commodities, which again reinforces a concern with epistemic issues. It is interesting, for instance, to read Thomas Robert Malthus on his objections to free trade. Malthus favors a form of trade protectionism that would limit the outside import of corn (the early-nineteenth-century word for grain) *and* subsidize both domestic production of corn and export of corn. The bounties for export would make sure the domestic supply was robust and that supply could be redirected to domestic demand in times of need. In similar fashion, restrictions on corn imports would ensure that foodstuffs did not end up all being produced in foreign countries. Malthus is notably suspicious that other nations would not allow grain to be sent to England if a general war or crisis occurred. On top of those trade restrictions, Malthus entertains the idea of the government storing some of that food in granaries to use in times of dire need. Taken together, this is a program for a kind of "industrial policy" directed at creating permanent excess capacity in the agricultural sector, so that there is more grain at hand in the domestic market.[11]

The same informational complexity that makes markets more necessary and more valuable also makes government intervention more difficult, and I am focusing here on interventions for national security grounds. A consistent Hayekian thus should be especially worried about national defense arguments, for they are something that advanced, decentralized, and complex economies are poorly geared to respond to.

To be clear, the appropriate level of Hayekian worry could indicate the appropriateness of either a higher or lower degree of government

[10] On the issues surrounding these dyes, see Christopher Rowland, "Covid Shutdowns in China are Delaying Medical Scans in the U.S.," *The Washington Post*, May 11, 2022.

[11] See Thomas Robert Malthus, *An Essay on the Principle of Population: The 1803 Edition* (New Haven, CT: Yale University Press, 2018), III.IX, X, 349–69; Thomas Robert Malthus, "The Grounds of an Opinion on the Policy of Restricting the Importation of Foreign Corn" intended as an Appendix to "Observations on the Corn Laws," in *The Works of Thomas Robert Malthus*, vol. 7, ed. Edward A. Wrigley and David Souden (London: Pickering, 1815 [1986]), 151–74. For useful background, see Patricia James, *Population Malthus, His Life and Times* (London: Routledge & Kegan Paul, 1979), 249–63. For a survey of Malthus on protection, see Samuel Hollander, *The Economics of Thomas Robert Malthus* (Toronto: University of Toronto Press, 1997), chap. 17. On the one hand, it is easy to say that Malthus was wrong about protectionism, as most nations have relied on international trade to procure themselves cheaper and more abundant foodstuffs. A lot of actual famines, such as in Maoist China, were accompanied by attempts at domestic self-sufficiency in the food supply and even restrictions on food transport within China. On this point, see Frank Dikötter, *Mao's Great Famine: The History of China's Most Devastating Catastrophe, 1958–1962* (New York: Walker Books, 2010). In defense of Malthus, however, he was not arguing for nationalization of the food supply or even central planning, but rather, a series of taxes and subsidies to shift the equilibrium toward greater national self-sufficiency for Britain. Today, many countries still use subsidies and tariffs to boost their margin of self-sufficiency with their food supplies. While many economists object to such policies, it would be wrong to consider them mere archaic curiosities. Malthus laid the groundwork for those policy approaches.

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intervention. You might conclude that government has to work especially hard on these national security arguments to get them right. Alternatively, you might conclude that the task is hopeless and that we need to learn to live with lower levels of national security.

To sum up this section, we have in hand two key problems, both feeding into a potential lack of economic robustness. The first is excess complementarity and excess reliance on particular inputs. The second is the epistemic issue of understanding how supply chains are put together at all.

III. Is Everything a National Security Argument?

Once we recognize that semiconductor chips, vaccines, and masks may be covered by a national security argument, where exactly do we stop?

One recent development, found both on the Left and the Right, is to expand the scope of national security arguments. For instance, it is a common claim of politicians that an America shorn of manufacturing jobs will have a difficult time standing up to China. In part this is a literal claim about the importance of manufacturing jobs for, say, building Navy ships. However, the argument has become much broader. An America without many manufacturing jobs is painted as a weak country with an ailing Rust Belt, unemployed or underemployed men, and in general lacking in the ability to "get things done" in the physical world.

This essay is neither the time nor the place to assess such broad claims; perhaps they are not easy to assess within standard frameworks of social science. The difficulty of assessment, however, is in part the point. Most of the Hayekians I know scoff at such claims, citing the theory of comparative advantage and portraying an America moving toward better and higher-paying jobs. Once again, though, the Hayekian tension resurfaces. If we are so ignorant of underlying economic and social interconnections, how do we *know* that such arguments are false? Might those interconnections possibly be present in our world? If we seek to reject this national security argument outright, it seems we are asserting claims to knowledge of the underlying structure of the economy that do not mesh with our other Hayekian claims.

If we must be somewhat agnostic about this kind of national security argument, where does this leave us? A proponent of national security arguments might be happy with such a conclusion. After all, the gains from having a secure nation are large and, in many settings, the costs of trade restrictions are fairly small. The output restrictions and higher prices of tariffs might amount to a few percentage points of gross domestic product (GDP), but consider the trade-off. If someone said that a policy would significantly boost national security with a probability of (only) five percent, but lead to an increase in the costs of trade restrictions with certainty, is that worth it? A lot of people might think it is, so the Hayekian framework opens the door for a particular kind of national security argument. A Hayekian could try to argue that the chance of boosting national security is well below

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five percent or that perhaps the tariffs will themselves through some mechanism harm national security. Maybe. How much epistemic certainty is going to be possible here, though, at least within a Hayekian framework? Once again, national security arguments may take on new lives.

In October of 2021, the Biden Administration announced that it accepted the prior Trump Administration claim that steel is a U.S. national security issue, so that there was a national security justification for steel tariffs. The protection is against European Union (EU) steel imports, however, not Chinese steel imports, so the national security connection here is not obvious, given U.S. alliances and generally decent relations with EU nations.[12]

As American politics polarizes, national security arguments are becoming broader yet. The relevant background here is that many Republicans consider Democrat rule as outright disastrous for national security—and vice versa. Such views are much more pronounced now than they were ten or twenty years ago. It is not so much about policy disagreement in foreign policy areas (for example, both Donald Trump and Joe Biden favored U.S. withdrawal from Afghanistan), as about the belief that the elites of the other side are corrupt, rotten, and dangerous.

In a world with such perceptions, just about any issue that can influence an election becomes a national security issue. Do voters hate inflation? Often, yes, so that could make inflation a national security issue. Abortion could be a national security issue. The prices of housing and gasoline could be national security issues, and so on. Anything that is politicized could determine who is the next president and the next party to control U.S. Congress. What could be a more important national security issue than that?

We are again at an awkward impasse. Presumably, some of the readers of this essay are polarized and perhaps I have talked them into a significant expansion of the national security argument. They might then move to a "politics above all else!" vision of economic policy and elevate the vision of a vote-maximizing politician over that of a more technocratic outside advisor. Presumably, some of my readers are not themselves so polarized and they do not see the stakes in U.S. elections as being so high. However, we must again consider expected value in such calculations. Is there not a five or ten percent chance that who is elected the next U.S. president is a big deal for national security and that we will be able to tell in advance which candidate would be better and which would be worse? We could again end up pushed toward an expansive vision of national security arguments, even if "it doesn't matter so much who wins" is our modally most likely view of the world. In terms of expected value, we still have to worry about national

[12] On this episode, see Aime Williams, "Biden Official Says Protecting US Steel a National Security Issue," *Financial Times*, October 3, 2021, https://www.ft.com/content/e1f33362-2c36-4f99-9b11-7dcd82ee7c06.

security. Again, the epistemic modesty of the Hayekian framework is not ideal for rescuing us from this dilemma.

IV. Are Economies Evolving More Substitutes or Greater Complementarity?

The next question concerns how supply chain problems evolve over time and how we might fix them or at least minimize their problems. That requires consideration of the concepts of substitutes and complements.

Substitutes are inputs that, when the price of one input goes up, people use more of another input. When the two inputs are complements, an increase in the price of one input will *limit* the use of the other input. More conceptually, substitute inputs are alternatives for each other, whereas complements work together, just as a left shoe and right shoe each make the other more valuable; it is difficult to hobble around on one shoe.

Here is a recent practical example of a complement, showing how complements can hold up production: "We're sitting on $2 million in inventory for one $30 part." Those are the words from one tricycle seller in Florida, circa 2021, because the company was waiting for the delivery of "rear derailleurs," a small but important tricycle part built in Taiwan. Shipping delays and high prices for shipping containers, brought on by the pandemic, were part of the problem. I choose that example for its starkness, as fortunately tricycles are not (yet?) a national security issue. Furthermore, over time we will find ways of making them without that part, if that should prove necessary.[13]

A less transparent but highly important complement (for some goods) is shipping. If everything else in a supply chain goes right, but the goods cannot be shipped to the United States and then unloaded in an orderly manner, the rest of the success is for naught. Some goods can be flown in, driven in, or even walked in, but in many cases, especially for heavy, high-volume goods, shipping is the relevant option. As of this writing, an unprecedented number of ships have been waiting in the water, loaded with goods but kept out of excessively crowded U.S. ports.

To the extent substitutes are widespread, national security arguments are weaker. If steel from South Korea is a good substitute for steel from the EU, maybe steel tariffs on the EU are not justified on national security grounds. If lower-quality semiconductor chips can substitute for higher-quality chips, again national security arguments will be correspondingly weaker, because the lower-quality chips are more readily available from a greater number of diverse sources. You may not wish to resort to the lower-quality substitute, but still its availability affords some measure of protection against supply cut-offs of the higher-quality product.

[13] See Jeanna Smialek and Madeleine Ngo, "Why Supply Chains Are a Mess," *The New York Times*, August 24, 2021.

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Substitution may occur at the level of national defense itself. If America cannot rapidly build new ships, perhaps the U.S. can deploy its nuclear-armed submarines more effectively. Surely, they are a formidable weapon, threat, and defense mechanism. If America cannot build and launch the right kind of satellites to run a GPS-based land campaign, perhaps the U.S. can instead threaten its enemies with their intercontinental ballistic missiles. It does seem that with a formidable array of nuclear weapons, American national security is guaranteed for a long time to come. These arguments are sometimes used to show that America's loss of much of its manufacturing base is tolerable from a national security point of view. In essence, nuclear weapons are a substitute for building more warships.

It is worth noting some qualifiers. If nuclear weapons are "the universal substitute" when it comes to national defense, that puts a heavier burden on the maintenance, upkeep, and most of all the rhetorical and tactical deployment of nuclear weapons threats. Making nuclear weapons more important may itself damage U.S. or also global security. For one thing, a world where nuclear weapons are more important may be intrinsically more dangerous. For another thing, nuclear weapons hints and threats may not be suitable for most smaller-scale conflicts. If Beijing launches nuclear missiles at the U.S., the U.S. might nuke them back, but can the U.S. really threaten to nuke Beijing over an invasion of Taiwan? (Or Quemoy and Matsu?) Probably not. Reliance on nuclear weapons alone thus probably means a world where America progressively loses influence and allies, which returns us to the relevance of other national security issues, even if nuclear weapons can be used to forestall outright conquest and invasion.

In other words, nuclear weapons may be suited for national defense only in a limited sense of that term. We can think of nuclear weapons as a highly specialized technology that are good for only a few "brute" purposes, most of all deterring nuclear threats from other nations. We again return to a Smithian irony when it comes to national defense. If increasing economic specialization elevates the import and status of nuclear weapons, at least for the United States, that is one important implication of the growing division of labor that economists never told us about.

It is a key question whether market economies over time evolve more substitutes or more complements. To the extent that substitutes become more likely, that minimizes some sources of disruption from supply chain problems.

On the one hand, increasing wealth and the growing number of goods might boost substitutability. For instance, in a primitive economy oxen may be a primary means for pulling the plow, but economic growth gives rise to a wide variety of machines and tools to help farmers accomplish comparable ends. This mechanism is both straightforward and powerful.

On the other hand, forces favoring complements should not be ignored, especially in economies with rapid growth and lots of innovation. Many innovations, such as high-quality semiconductor chips, require extreme

levels of precision and a combination of many different inputs, including specifically talented human labor. That makes them vulnerable to disruption. Furthermore, once such chips are available, a dynamic economy will rush to apply them to as many different uses as possible. Indeed, we have such chips in many other goods and services, including cars, household appliances, and increasingly in new homes. That means chip use will be somewhat strained and at the margin those chips will be difficult to replace. While this is probably not the dominant trend in the current American economy, all goods and services considered, those chips nonetheless will have a high value-added contribution to GDP and to national security.

On top of this logic, the contemporary world seems to be favoring innovations with high fixed costs and low marginal costs, software being the paradigmatic example. That cost structure often leads to relatively high degrees of market concentration; for instance, Google accounts for most of internet market search and Meta (formerly Facebook) has a significant presence in social networking. Given learning curves, Tesla may end up with a big "decreasing average cost advantage" in the manufacture of electric and self-driving vehicles. In the resulting equilibrium, the level of concentration in the market can give rise to points of vulnerability, whether this is defined across a single company or a single nation or regional area. It took the actions of only two firms—Visa and Mastercard—to prevent most Russians from being able to spend their funds abroad.

There is no one satisfactory metric by which we can judge whether substitutability or complementarity is becoming the greater force in growing economies. The relevant point is simply that the cases of complementarity, even if they are not dominant, retain their significance precisely because they are complements and large parts of the economy may depend on them. As specialization proceeds, increasing returns set in, and markets build highly effective production teams, we again are left with potential supply chain vulnerabilities and "choke points."

Furthermore, some arguments suggest that markets lead to insufficient substitutability in supply chains. It may be more profitable to produce complements than substitutes, due to the greater "indispensability" of the former. Individual suppliers who seek higher profits or supply chain bargaining power may not take into account the greater social vulnerability that results from their decisions, applied collectively to the broader supply chain. This again returns to our key theme of insufficient robustness. According to a study of supply chain inefficiencies and vulnerabilities: "Summarized in the end, all of these policy implications have a simple message: robustness is under-supplied."[14]

[14] Jiang, Rigobon, and Rigobon, "From Just in Time," 6, which is from more of an operations research perspective. For one version of this argument, see Gene M. Grossman, Elhanan Helpman, and Hugo Lhullier, "Supply Chain Resilience: Should Policy Promote Diversification or Reshoring?" (National Bureau of Economic Research Working Paper No. 29330, October 2021).

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A. Benefits of complementarity

Although complements in supply chains are problematic, they also have an upside. In particular, they can be a force for peace and continuing trade rather than just a national security problem. For instance, consider a situation where nations are dependent on each other for a variety of goods; in other words, complements cut both ways. The resulting complexity of the trade relationships might make for safe and orderly relations. If one nation were to cut the other off, the second nation could retaliate, thereby encouraging the maintenance of cooperation.

In similar fashion, the complexity of vaccine production in some regards *helped* keep trade in vaccines up and running. For instance, the AstraZeneca vaccine originated from Oxford, but much of the production took place on the European continent. Nonetheless, the U.K. government was the buyer first in line with a confirmed contract for large numbers of doses. For a while there was talk of cutting off the EU-based supply of those vaccines to the U.K., but it was realized that some of the productive inputs came from the U.K. itself. If the EU cut off the vaccines, the U.K. could retaliate by cutting off some of the relevant vaccine production inputs. The EU then would not be left with much effective domestic capacity for vaccine production at all.[15]

While cooperation held in this instance, some trade-offs did occur. The Serum Institute of India, in response to government directives, reneged on its export commitments and redirected those vaccines to domestic use in India. The losing countries typically were poor and not technologically advanced in terms of supplying vaccine inputs, so they had no tools of effective retaliation. India's domestic redirection of the vaccines was able to stick in this case.[16]

Sometimes, incentives for greater cooperation, as might result from complementarity, run through a central hegemon. Consider computer chips. A 2021 study by Boston Consulting Group and the Semiconductor Industry Association estimates that it would cost a nation at least $1 trillion to create a fully self-sufficient, high-quality chip supply chain; even then, chip prices for that country likely would be higher. The practical upshot is that most countries cannot realistically pursue this option. That means, in practice, that many countries have a strong incentive to remain on "good enough" terms with the United States, because the U.S. Navy is the world's top protector of shipping lanes. I have already mentioned how high-quality semiconductor chips come from Taiwan and South Korea, but the chips are not typically purchased directly from those nations. Malaysia, for instance, is an important intermediary point, but if your country wishes to purchase

[15] See Bown and Bollyky, "How COVID-19 Vaccine Supply Chains," on this and related issues, with 47–48 covering interdependence in particular.

[16] Bown and Bollyky, "How COVID-19 Vaccine Supply Chains," 19–20.

chips from Malaysia, free and open trade may rely on various supportive protections from the United States.[17]

The United States controls other choke points, typically based on the assembly of many complementary inputs. One of those would be the international payments system SWIFT, run by an international consortium, but falling under de facto American and Western European control. If the Western alliance wishes to boot your country out of that payments system, it can do so, as recently illustrated by actions against Russia. American institutions also play a major role in discovering, sharing, and distributing "intelligence" obtained through its extensive surveillance networks. Access to that intelligence is used to induce many other nations to follow an American lead on foreign policy. To be clear, I am not arguing that other nations cooperating with the United States always makes for better outcomes. Rather, the point is that complementarities and dependence, under some conditions, can lead to more cooperation rather than less.

B. Redundancy through multiple suppliers: Is it really just a China problem?

Given the importance of substitutes and complements, it is crucial to know when substitution is most likely to be difficult. One possible set of problems arises when all or most of the inputs are found in a single country. In that case, political problems and trade restrictions could result in supply cut-offs with no clear substitution in response.

In that setting, supply chain concerns will often be problems unique to dealing with the nation of China. To cite one possible example, a May 2022 estimate from the Biden Administration suggested that China then accounted for 80 percent of rare earth elements production and refining for the United States, 61 percent of global lithium (a key component for batteries), 97 percent of silicon wafers for solar panels, and 80 percent of global lithium-ion battery recycling capacity.[18] Those results are no mere coincidence; because of its enormous scale, number of engineers, and relatively cheap labor, China has taken on outsized importance in supply chain arguments. In this regard the rise of China is an unprecedented development; the Soviet Union, 1930s Japan, and Nazi Germany were not so important in U.S. supply chains. Even if a particular sector is competitive within China, the United States cannot rely on Chinese exports if a major foreign policy crisis with China were to arise.[19]

[17] "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," Boston Consulting Group/Semiconductor Industry Association Report, April 2021, https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/.

[18] See Todd N. Tucker, "Supply Chains Endanger American Security. Here's What Biden Is Doing," *The Washington Post*, May 17, 2022.

[19] For a look at how the United States responded to supply chain issues during World War II, see Maury Klein's useful *A Call to Arms: Mobilizing America for World War II* (London: Bloomsbury Press, 2013).

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To continue with the rare earth elements example, originally both China and the United States produced many of the "rare earths" important for producing high-tech and national security-relevant items. However, this production is now largely confined to China, as the United States passed environmental regulations that made domestic production of the relevant rare earths too costly. The U.S. is thus more dependent on China for rare earths than it was twenty years ago.

This rare earths example illustrates yet another point about supply chains. When complements are important, the proper conclusion is not to bring all production into the domestic orbit. A domestically produced vital input can dry up, too, due to power shortages, strikes, terrorist attacks, and many other problems, including excessive environmental regulation. Ideally, an essential input should be available from multiple sources around the globe, domestically and from a number of foreign nations. That is the truly diversified position, which in turn means that national security arguments, while they may sometimes point in "pro-domestic production" directions, do not have to be antitrade or anticosmopolitan per se.[20]

Baby formula shortages in 2022 illustrate the importance of multiple sourcing for supply chains. For regulatory reasons, the U.S. Food and Drug Administration does not allow the U.S to import most baby formula from the European Union. Thus, when there were production problems at one major North American baby formula facility, the supply was endangered and a shortage ensued. Normally, foreign suppliers might have stepped into the gap, but here that option was hindered. The resulting problem was not one of national security, but the example indicates nonetheless the virtues of multiple sources of supply, across multiple countries, and not domestic supply sources alone. The solution here is not to plumb for greater self-sufficiency in baby formula (which failed), but rather, to diversify sources of supply.

It would be wrong to say that supply chain problems are "just China problems," but they are most likely China problems. Multiple regions for sourcing is often the best we can do to produce more robustness, whether the issue concerns China or not. So we should be concerned whenever China is the major supplier of some good or service. Furthermore, we should be concerned whenever the United States or other nations have put up trade barriers that artificially limit the number of potential substitutes, most of all when those substitutes will come from a multiplicity of different nations.

V. Further Applications

Tying together supply chain analyses, socialist calculation, and national security arguments helps us understand some other economic issues. I will

[20] On this point, see Richard Baldwin and Rebecca Freeman, "Risks and Global Supply Chains: What We Know and What We Need to Know" (National Bureau of Economic Research Working Paper No. 29444, October 2021).

consider both carbon taxation and corporate social responsibility, two major issues as of late.

A. Carbon taxation

Taxing carbon is one of the most popular ideas among economists—and on a largely bipartisan basis. Since we must tax something, surely there is a strong argument—almost an *a priori* one—for taxing that which has negative externalities. Due to the serious issues surrounding climate change, carbon emissions are a plausible target for such taxes.

I, too, support a carbon tax, yet I view the case for it as less airtight than many other economists suppose. I also am reluctant to refer to a carbon tax as a "market-based" solution rather than as a "top-down" or "interventionist" approach to climate change. Some right-leaning advocates of a carbon tax, such as Greg Mankiw, try to describe a carbon tax in those terms, to make it more palatable to others and perhaps to themselves as well.[21] I wish such a description were true, but mostly it is not.

Implementing a carbon tax faces classic issues of supply chains, complementarities, and also socialist calculation. The problem arises when we try to calculate the carbon impact of our various consumption decisions. Some decisions might qualify as "easy targets," such as driving a gas-guzzling car or opening a new mine for dirty coal. Eating beef may be another example where you could apply a carbon tax without much hesitation. Still, for a larger quantity of decisions the sign of the appropriate tax will not be clear, to put it mildly.

Natural gas, for instance, typically is cleaner than coal, but it still is associated with carbon emissions. Should it be taxed or subsidized? That will depend on the relevant alternatives to natural gas, such as solar, wind, and coal. How dirty is hydrogen power these days? The questions become yet more difficult when we try to calculate the proper magnitude of such taxes, when a tax is called for. Do we know the relevant elasticities of adjustment? Have we decided how much we are trying to hit short-term versus long-term emissions targets? Furthermore, *to which unit* do we apply the tax? To the number of homes and businesses served? As a percentage on their electricity bills? The number of British thermal units (BTUs) generated? BTUs generated weighted by location and time of day? Depending on the revenue of the using business and its share in GDP?

I am not suggesting that such questions are impossible to answer or to address at least in a "good enough" manner. The point, instead, is that one needs an ambitious planning apparatus, with an accompanying bureaucracy, to do so. There is no obvious "market solution" to be pulled down off the shelf.

[21] N. Gregory Mankiw, "The Key Role of Conservatives in Taxing Carbon," *The New York Times*, September 4, 2015, https://www.nytimes.com/2015/09/06/upshot/the-key-role-of-conservatives-in-taxing-carbon.html.

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If you would like to consider further complications, imagine a carbon tax in a Hotelling model where most of the oil will be pulled out of the ground anyway and the taxing planner only controls when.[22] In such models, a current carbon tax, combined with a rising carbon tax over time, actually will *boost* oil extraction today. If you know the tax will be higher later on, pump the oil now while the tax is relatively low. Again, I am not claiming a kind of epistemological nihilism here, as I think we can settle on a "good enough" version of a carbon tax. I am simply pointing out once again that the correct level of the tax is hardly self-evident or derivable from first principles.

When it comes to green energy, a classic and common mistake is the insistence of many people on "locavorism." Supposedly, we should eat only locally grown foods to limit the carbon and other environmental costs of food transport. Do you really need to have your asparagus flown in from Chile, when there is perfectly good local squash available in your supermarket and nearby farmers' markets? That particular example might succeed, but more broadly researchers have concluded that locavorism is not an effective anti-carbon strategy. Transportation costs are typically a low percentage of overall food costs. Also, the energy expended on transportation often results in greater energy savings elsewhere, such as in growing the food or most appropriately using raw materials and fertilizer.[23]

Already you can see how much the plot is thickening. The examples can get much more complicated yet. Take San Francisco's action to ban one-use plastic bottles from airports. When I walk through San Francisco International Airport, I cannot get the plastic water bottles I am used to swigging from. Such bottles were considered environmentally unfriendly and it is easy to see how they might be. Still, if you look around the airport a little more closely, you will see that soft drinks hardly have been banished. Instead of drinking that Dasani water, you might go buy a Coca-Cola or maybe one of those sweetened fruit juices in a *glass* bottle. Do those have a better or worse environmental and carbon impact than a bottle of Dasani water? A Coca-Cola, for instance, has a fantastically complex supply chain, spanning numerous countries and dozens or hundreds of different materials, including for the cola, the bottle, and the crates that ship the final product.

It is difficult to compare the carbon friendliness of the various alternatives or even to ascertain how many people thwarted from buying that water ended up with a different drink instead. Or did they just go thirsty? In general, the more complex the supply chains, the more difficult it will be to estimate the carbon friendliness or unfriendliness of a particular good or service.

[22] See Harold Hotelling, "The Economics of Exhaustible Resources," *Journal of Political Economy* 39, no. 2 (1931): 137–75.

[23] For a survey of the empirical critiques of locavorism, see Tyler Cowen, *An Economist Gets Lunch: New Rules for Everyday Foodies* (New York: Dutton, 2012).

In the days of America's Clinton Administration, there was a concerted (failed) effort to pass what was then called a "BTU tax." You can think of that as an early attempt at a carbon tax. The bill turned out to involve creating a large bureaucracy empowered with determining the carbon-related damage resulting from various goods and services and resulting from various industrial inputs. The final result would have been the creation of a large number of categories of different goods, noting of course that carbon contents of these goods would change with innovation and with basic economic development. How was the bureaucracy to keep up?

At the time, Newt Gingrich's U.S. House Republicans were scathing, comparing the BTU tax to a kind of central planning and stressing the bureaucratic commitments entailed in its passage. Whether or not those Republicans should have supported the bill nonetheless is not the point here. I am instead suggesting that their purely descriptive take on the bill was an accurate one, as can be verified by reading descriptions of what the bill would have entailed.

The broader relationships here are sadly ironic. We are familiar with Adam Smith's observations about growing complexity and the division of labor; those remain some of the most fundamental contributions of economics, but here is the rather unpleasant catch: Smith's mechanisms also make it more difficult for minimalist government intervention to work. What once might have been relatively simple government interventions increasingly come to resemble "planning" as economies grow more complex. The implementing bureaucracy has to be much larger, interdependencies play a greater role in assessing any policy, and the Hayekian knowledge problems become much greater. Smith's account was originally an understanding of the growth of market society, but unintentionally it is also a possible explanatory mechanism for both the growth of government and the decline of governmental quality. In essence, government policies have to manage "supply chain" problems all the more as an economy grows more complex. Those policies, even if better than a laissez-faire approach, might nonetheless come in as relatively poor performers.

B. Corporate social responsibility

The analysis of corporate social responsibility tracks that of a carbon tax, albeit with differently named variables. Nonetheless, the same kinds of calculation difficulties arise.

Let's say a company sets out to eliminate or minimize racism or some other disagreeable practice in its supply chain. Most likely, there will be obvious cases of racist practices that can be pinpointed and either reformed or boycotted. However, at some point the complexity of the supply chain becomes a significant issue. How is a business or nongovernmental organization (NGO) to accurately judge which of two supply chains is more

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racist than another? There is both a moral pluralism problem, namely, how to compare different instantiations of racism, and also an epistemic problem, namely, that the entirety of the supply chain is difficult to grasp and thus not every instance of racism can be pinpointed.

I recall once having a conversation with an involved corporate agent, who was highly placed in a major company that had a market presence in selling seafood. The person swore to me—sincerely, I believe—that said company could not accurately ascertain where in their supply chain might be the use of slaves to catch seafood. Their supply chain was not transparent, even to them, and this was admitted in a despairing tone of voice. Of course, the more the world tries to seek out and punish such affiliations with slavery, the more the enslavers will take care to disguise and cover up what is really going on.

The same problem holds all the more for child labor, which is also a component of many supply chains, ranging from seafood to chocolate. How old are those kids anyway? Who is supposed to ask whom? What if the kids are told not to show up for work when an inspector comes in? Is it so easy for the inspectors to regularly penetrate the forests of Madagascar and the small, seafood-rich islands in the Philippines?

We thus arrive at another general principle about the growing division of labor and economic complexity. Being an "economic or corporate moralist" involves a growing epistemic and practical burden. It is easy enough to boycott Mississippi cotton in 1840. It is much more difficult to know, circa 2022, where you should buy your fish or your chocolate.

Typically, we think of governments as regulating the moral conduct of business, but in an interesting switch we now sometimes see businesses trying to regulate the moral conduct of governments. For instance, some of Wall Street's major buyers of state and local government bonds are starting to judge the race-linked performance of those governments and to allocate capital accordingly.[24]

Five major players in finance—BlackRock; Goldman Sachs; Lord, Abbett & Co.; Morgan Stanley; and Vanguard—are developing a questionnaire for local government to fill out prior to raising money on the bond market. The questions ask about efforts to combat race-based inequality and racial composition of the government's workforce, among other race-relevant matters. The hope is that municipal governments will help investors decide which issues to buy; the project is called the Municipal Issuer Racial Equity & Inclusion Engagement Framework. A clear signal is being sent to these municipal governments, especially since the involved financial firms are such large players in these bond markets.

[24] Danielle Moran, "BlackRock, Goldman Join Racial-Justice Push in Muni-Bond Market," *Bloomberg*, September 24, 2021, https://www.bloomberg.com/news/articles/2021-09-24/blackrock-goldman-join-racial-justice-push-in-muni-bond-market.

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It remains to be seen how these plans will develop, but they represent broader trends in corporate social responsibility, namely, an attempt to channel resources to firms or, for that matter, governments that pursue particular policies with respect to race, social justice, the environment, or other salient social issues. As in the above cases, a version of the socialist calculation debate also applies to these supply chains. You can ask about the racial composition of the Memphis city public works commission, but what about the racial composition of their independent contractors? How about for the firms that sell to their racial contractors, and so on? Once we get past upfront symbols, which municipal governments actually do the most to combat racism? The ones with the best school systems? The ones with the most prominent minority representation? The ones with the best-behaved police forces? The ones with the most effective public health or social welfare programs? The answers are not obvious.

Another example of markets regulating governments is when private associations organize boycotts of states that pass undesired legislation on issues of gay rights, abortion, transgender rights, and so on. North Carolina, for its bathroom laws, and Texas, for its abortion policies, have been two states on the receiving end of such boycotts. At least in theory, such boycotts are aimed at directing public sector policies in directions amenable to the boycotters. The actual results of such boycotts, however, remain an open question, in part due to the complexities and interdependencies of supply chains. If a California-based institution will not hold its yearly convention in Texas, does that change Texas policy? Or does it further reinforce the cultural and political split between Texas and California? Consider instead government-to-government boycotts. If the California state government will not reimburse employee travel to a group of specified southern states, does that change policy? Or is the goal simply to make a statement and give California voters a feeling of satisfaction because they are now less affiliated with states they might find objectionable? Once again, with complex supply chains the answers are not always obvious.

VI. Concluding Remarks

Supply chain problems have been understudied by economists. One implication is that it is difficult to tell where national security arguments begin and end. That may weaken some of the traditional arguments for free trade for the same reasons that we buy into the difficulty of rational economic calculation in a socialist society. It is difficult to keep national security arguments for protectionism restricted to small segments of the economy. That said, alternative arguments for free trade, based on the possible stability of mutual interdependence and multiple sourcing, may become more important. Furthermore, in a well-developed market economy some kinds of government policy, even if desirable, will become *much*

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more difficult to pull off. For instance, it can be difficult to know exactly which parts of the supply chain need to be targeted. I also consider why complex supply chains may create problems for a carbon tax and for the notion of corporate social responsibility.

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