The Logic of Strategic Assets: From Oil to AI

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Abstract

What resources and technologies are strategic? This question is often the focus of policy and theoretical debates, where the label “strategic” designates those assets that warrant the attention of the highest levels of the state. But these conversations are plagued by analytical confusion, flawed heuristics, and the rhetorical use of “strategic” to advance particular agendas. We aim to improve these conversations through conceptual clarification, introducing a theory based on important rivalrous externalities for which socially optimal behavior will not be produced alone by markets or individual national security entities. We distill and theorize the most important three forms of these externalities, which involve cumulative-, infrastructure-, and dependency-strategic logics. We then employ these logics to clarify three important cases: the Avon 2 engine in the 1950s, the U.S.-Japan technology rivalry in the late 1980s, and contemporary conversations about artificial intelligence.

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Overview

In March 2018, when the U.S. Trade Representative released its Section 301 report on China’s unfair trade practices — one of the first volleys in a trade war — astute observers noted that the report singled out a relatively obscure Chinese technology plan: “Made in China 2025 [zhongguo zhizao 2025].” Amidst the bluster of tariffs on steel and soybeans, these analysts understood that “Made in China 2025,” which prioritized ten “strategic industries (zhanlüe chanye),” posed the “real existential threat to U.S. technological leadership.” Indeed, competition over “strategic” goods and technologies has become a focal point in the broader U.S.-Sino rivalry, though the crucial step of clarifying what makes an asset “strategic” has often been neglected.

This definitional vagueness is neither new nor limited to the U.S.-China rivalry. For centuries policymakers and theorists have debated which goods and technologies deserve the “strategic” descriptor. These conversations matter. David A. Baldwin’s characterization of the debates over strategic assets, written in 1985, remains true today: “Widespread misunderstanding of the concept of ‘strategic goods’ is one of the biggest impediments to intelligent discussions of economic statecraft.” Analysis on strategic assets would enhance discussions of the targets of export controls and industrial policy, key drivers of economic and military competition, and assessments of national power.

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1 There were 116 mentions of “Made in China 2025” in the Section 301 report. The plan was first issued by the Chinese State Council in May 2015. The ten strategic sectors included high-end numerical control machinery and robotics, energy-saving and new energy vehicles, biopharmaceuticals and high-performance medical devices, etc. Laskai 2018.
2 For instance, in October 2018 the U.S. Department of Treasury established a pilot program that increased scrutiny of inward foreign investment in “critical technologies,” a broad category that includes defense equipment as well as a similarly broad subcategory of “emerging and foundational technologies” which has not been defined. U.S. Department of the Treasury 2018.
3 Baldwin 1985, 214.
4 On export controls, see Crawford 1993; on industrial policy, see Fong 2000.
5 On high-value-added industries and mercantilism, see Weber and Zysman 1992; on the conflict risks associated with strategic minerals, see Uchitel 1993.
6 On assessments of China’s power vs. that of the U.S. based on strategic technologies, see Beckley 2012; Monteiro 2014, 124-142; Brooks and Wohlforth 2016.
How should national leaders identify strategic assets? In this paper we present a unified theoretical framework based on an asset’s connection to important rivalrous externalities, such that optimal transactions involving these assets will not be achieved by markets and individual national security entities themselves. Thus, strategic assets are those for which attention from the highest levels of the state is required in order to secure national welfare against interstate competition.

This framework can be roughly summed up in the following “strategic formula” for goods and technologies:

**Strategic Level of Asset = Importance * Externality * Nationalization**

The strategic level of an asset is a product of the following three factors:

1. **Importance**: an asset’s economic and/or military utility (some sectors, e.g. freight transport, contribute more to economic growth than others, e.g. high-end fashion).

2. **Externality**: the economic and/or security externalities associated with an asset, such that uncoordinated firms and individual military organizations will not optimally attend to the asset. (e.g. the positive externalities generated by research into foundational technologies, which private actors under-invest in because they do not capture all the gains from spillovers).\(^7\)

3. **Nationalization**: the degree to which these externalities differentially accrue to the nation and one’s allies, and not to rivals (e.g. fundamental research in medicine has positive externalities, but they may easily diffuse to other rival nations, which limits an asset’s strategic level).\(^8\)

\(^7\) Even the most important assets, e.g. nuclear weapons, may score low in this factor if states have already internalized all the externalities associated with these assets.

\(^8\) Assets which are important and have substantial externalities, but lack nationalization (so the externalities spill roughly equally on strategic friends and rivals) are not strategic, in our definition, as it does not have rivalrous implications. Nevertheless, such assets, such as research into basic medicine, are still worthy of government attention, as they provide absolute benefits.
Of these three factors in our framework, we will focus on what we regard as the most illuminating aspect of this equation: the existence and character of externalities that demand the attention of the state. Conceptualizing the strategic level of assets through the lens of externalities enables the coverage of a broad range of strategic interactions, as information asymmetries, transaction costs, and other frames of market failure can be expressed as externalities. The concept of externalities is an economic one, and is typically applied to private actors (firms, individuals). However, the concept can also be used for military entities, where the military entity (say the Navy) has a mission, remit, organizational competence, and incentive structure that does not wholly internalize the interests of other sub-national actors. Basing the framework on externalities also roots it in existing scholarship at the intersection of economics and national security.\(^9\)

Externalities come in many shapes, but we distill three forms of these externalities — the cumulative-, infrastructure-, and dependency-strategic logics — that cover a substantial range of the strategic qualities of assets (Table 1):

1. **Cumulative-strategic logic** involves assets and sectors with high barriers to entry linked to cumulative processes, such as first-mover dynamics, incumbency advantages, and economies of scale. These high barriers to entry lead the market to under-invest, and military organizations to require explicit state support to achieve nationally optimal investments. Aircraft engines [1945-present] serve as a representative example, as high research and development costs associated with these complex technical systems make it so that only a handful of firms can compete.

2. **Infrastructure-strategic logic** involves assets that generate positive spillovers across the national economy or military system, which sub-national actors (e.g. firms or military

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\(^9\) Recent works have outlined security externalities in the context of economic competition: Norris 2016; Kennedy and Lim 2018.
branches) under-invest in because they do not appropriate all the associated gains. These are often central technologies that complement and upgrade the national technological system. A representative example is railroads [1840-1860].

3. **Dependency-strategic logic** involves assets whose supply is concentrated in a limited number of suppliers. Due to the lack of substitutes, these assets are often vulnerable to supply disruptions. Nitrates [1914-1918] are a representative example, as the British naval blockade prevented Germany from importing nitrates from Chile, the world’s principal supplier.

| TABLE 1 The Logics | Description | Examples (Economic) | Examples (Military) | Examples (Both) |
|-------------------|-------------|---------------------|---------------------|-----------------|
| **Cumulative-strategic** | Associated with cumulative gains for a nation's firms and other sub-state actors which create high barriers to entry for potential competitors | Digital social networks [2000-present]10 | Stealth fighters [1945-present] | Aircraft engines [1945-present] |
| **Infrastructure-strategic** | Generates (diffuse) positive spillovers across the national economy or military system. These are often central technologies that complement and upgrade the national technological system | Electrical equipment [1900-1920] | Radar [1930-1945] | Railroads [1840-1860] |
| **Dependency-strategic** | Has few substitutes and serves as an input to a range of significant economic and military activities | Platinum [1960-present] | Nitrates [1914-1918] | Integrated circuits [1980-present] |

These logics illustrate that the strategic level of an asset is not intrinsic to the good or technology itself. Not only is an asset’s strategic level shaped by features of the international environment (e.g. the rate of cross-border diffusion of technology) but it is also affected by the particular strategy pursued by a state (e.g. one oriented around a land army, versus navy, versus economic might, versus soft power). Motivated by the present environment of U.S.-Sino rivalry, we focus on the strategy of a great power concerned about growing its economic and military strength vis-à-vis that of its peer...

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10 This notation gives our rough gauge of the date range for which the asset remained at a high-level of strategic significance for industrial great powers.
competitors; however, we also emphasize that our framework is valid and useful for contexts in which states are pursuing different strategies.11

Part 1 reviews the literature on strategic goods and technologies, revealing the myriad and oft-confused understandings of the concept. We synthesize from this literature our three underlying logics for the externalities linked to strategic assets: cumulative-strategic, infrastructure-strategic, and dependency-strategic. Part 2 develops these logics, embedding them within our externality-based conception of strategic assets, where we explain why firms and militaries fail to adequately internalize the benefits or risks of a particular good or technology. Crucially, we also show how our framework’s three logics can operate in the economic domain only, the military domain only, or both — a marked departure from standard accounts which view key military and economic assets in isolation.

Part 3 applies our three-logic conceptualization of strategic assets to two historical cases: the Avon 2 engine in the 1950s and the U.S.-Japan technology rivalry in the late 1980s. Out of the population of cases, these two periods generated a disproportionately large amount of deliberation over strategic goods and technologies, so they serve as a crucial test of whether our framework provides analytical value. Revisiting postwar debates over the strategic importance of the aircraft industry differentiates our view of strategic assets from the oft-used heuristic of “military significance.” The application of the three-logic framework to the U.S.-Japan case provides a landscape view for how policymakers assessed the candidate strategic goods and technologies in a particular period, with a focus on how U.S. policymakers mis-identified strategic assets.

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11 Suppose, for instance, a state wants to base its strategy on soft power. Our framework gives an initial cut for where strategic assets may be positioned: sources of cultural capital dominated by a single country with high barriers to entry, such as the Hollywood film industry (cumulative-strategic); instruments, such as strict national standards against corruption, that prevent companies from undermining a nation’s brand (infrastructure-strategic); social media sites that serve as vehicle of coverage for a particular country (dependency-strategic).
Finally, Part 4 considers the implications of our understanding of strategic assets for artificial intelligence (AI) and other technologies linked to the so-called “Fourth Industrial Revolution” of the current era. We highlight candidate assets that evince dynamics that are cumulative-strategic (big data platforms), infrastructure-strategic (smart manufacturing), and dependency-strategic (hardware for training AI algorithms). We conclude by considering possible extensions of our framework to classes of strategic assets besides goods and technologies as well as other strategic logics beyond the three we highlight.
Part I: Evolution of an Idea

In 1985, Baldwin wrote in his authoritative text on economic statecraft, “The controversy over what constitutes a ‘strategic good’ has been going on for thirty years.”\(^{12}\) Over thirty years later, the international relations field still sits at an impasse, making little progress in fleshing out what constitutes a strategic asset. Ostry captures the main issue: “The term ‘strategic’ has multiple meanings and its use is more confusing than enlightening.”\(^{13}\) As a result, a common refrain from many analysts is to give up on the exercise altogether and rely on gut feel — “they know a strategic industry when they see one.”\(^{14}\)

Previous theorizing about strategic assets can be grouped into three camps, distinguished by whether the focus of analysis is on: 1) military significance, 2) substitutability, or 3) strategic trade. Taking the perspective of a strategist concerned with the national interest, our framework and three-part equation for strategic assets (importance * externality * nationalization) highlights gaps and integrates insights from each of these camps.

**Military Significance Camp**

In the first camp, scholars emphasize the “military significance” of certain assets, arguing that the strategic quality of goods and technologies is determined by their military utility.\(^{15}\) The underlying assumption is that goods and technologies are “only strategic if they can be used for war, or converted for war, or processed into war-type goods.”\(^{16}\)

This view of strategic assets is prevalent in export control and defense industrial policy in countries around the world, especially the United States. For example, from 1989 to 1992, the U.S. Department of Defense published annual critical technology plans, which designated twenty

\(^{12}\) Baldwin 1985, 106. Baldwin traces this debate back to Wu 1952.
\(^{13}\) Ostry 1991, 88.
\(^{14}\) Teece 1991, 36.
\(^{15}\) See, for example, Adler-Karlsson 1968, 3.
\(^{16}\) Schelling 1958, 500.
technologies as critical for the long-term qualitative superiority of U.S. weapons systems.\textsuperscript{17} The U.S. export regime is based on a conception of strategic assets tied to military end uses and users.\textsuperscript{18}

Our framework views military utility as a necessary but insufficient component of an asset’s strategic level. Some important military assets are readily supplied through global markets, or produced domestically through existing organizational capacity, and thus do not require the high-level attention of the state because they do not exhibit rivalrous externalities. Small arms and military clothing, in many historical contexts, would be examples of assets which can be militarily significant but are not strategic.

**Substitutability Camp**

The substitutability camp’s view of strategic assets loosely corresponds to our framework’s third logic (dependency-strategic). These thinkers base a good’s strategic level on its substitutability, as captured by the degree to which it is critical to a significant economic or military process as well as the availability of substitutes for the good. In line with the dependency-strategic logic, Osgood defines a strategic good as “an item for which marginal elasticity of demand is very low and for which there is no readily available substitute.”\textsuperscript{19}

Elaborating this substitutability logic, Blanchard and Ripsman’s four-part “strategic goods test” represents an exemplary, rigorous attempt to differentiate among classes of goods and technologies in Anglo-German economic relations before the First World War.\textsuperscript{20} They first evaluate which goods were essential to national defense and economic well-being (importance in our equation) and then assess the impact of a supply cut-off by analyzing whether substitutes could have alleviated any disruptions (externality in our equation).

\textsuperscript{17} Crawford 1993, 16-17.

\textsuperscript{18} Meijer 2016 examines the challenge of globalization and dual-use technologies for U.S. export control policy.

\textsuperscript{19} Osgood 1957, 89; see also Haglund 1986; Baldwin 1985, 215.

\textsuperscript{20} Blanchard and Ripsman 1996.
Work in the substitutability camp is primarily concerned with the dependency-strategy logic, and this work does not look at other externalities that can give rise to strategic assets. Furthermore, the condition that the externality be rivalrous is rarely made explicit, plausibly because supply dependence is usually political, and thus can be made rivalrous. However, some dependence is in principle not rivalrous, such as two belligerents for whom a natural disaster disrupts their supply of oil, impacting them roughly equally.

**Strategic Trade Camp**

A third camp, with views rooted in the “strategic trade” literature, often lumps together economic versions of the two strategic logics missed by the substitutability camp. Strategic trade theorists highlight the extent to which particular industries confer large first-mover advantages, present high barriers to entry, and/or yield enormous spillovers.\(^{21}\) These considerations have become more important as global market structure has become more oligopolistic, in particular from the liberalization of foreign direct investment flows which enabled the consolidation of large-scale oligopolies in these industries.\(^{22}\)

In contrast to the substitutability camp’s recommendation that domestic sourcing helps protect supply, strategic traders emphasized other aspects related to the locus of production, such as ensuring that one’s firms can compete in cumulative-strategic industries and benefiting from spillovers associated with the production of certain assets. Still, analysis from the strategic trade camp is largely limited to the economic domain and rarely differentiates between infrastructure-strategic and cumulative-strategic concerns; our framework rectifies both of these shortcomings.

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\(^{21}\) Much of this literature is discussed in Krugman 1986.

\(^{22}\) Michalski 1991, 8.
Part II: Conceptual Framework

As outlined in the overview, under our framework, strategic assets are those for which there is an *important rivalrous externality* (Table 2). An asset’s “importance” is a necessary but not sufficient condition for something to be "strategic." Consider two examples in the cumulative-strategic domain. First, assets that present externalities but have low levels of “importance” are not strategic. A new technology for brewing that exhibits strong “learning by doing” characteristics may generate cumulative-strategic barriers to entry, but the scale of the brewing industry does not have a substantial effect on the economic or military power of nations. Conversely, an asset can be extremely important but not strategic. M240 machine guns are essential equipment for infantry platoons and armored vehicles, but they are so easy for most nations to build or acquire that they do not exhibit strategic externalities.

| Table 2: Tri-Logic Framework for Strategic Assets |  |
|---|---|---|---|
| I = importance, E = externality, N = extent to which externality differentially accrues to one nation vs rival ones. 1s and 0s are a binary simplification. All three are continuous variables. |  |
| | I * E * N | I * E * N | I * E * N |
| Strategic Logic | 1, 0, 0 | 1, 1, 0 | 1, 1, 1 |
| Cumulative | Steel [1990s-present]23 | ITER [1985-present]24 | Aircraft engines [1945-present] |
| Infrastructure | Real estate | Publications in basic science | Recombinant DNA tech [1980-present]25 |
| Dependency | Wheat | Ozone | Integrated circuits [1980-present] |

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23 Section three explains why steel became less strategic.

24 ITER, originally called the International Thermonuclear Experimental Reactor, is a 35-nation project to demonstrate the large-scale feasibility of fusion. Any competitor project, whether a single-firm or multinational effort, faces enormous barriers to entry, but any accumulated gains from ITER will disperse across countries.

25 Feldman and Yoon 2011 empirically demonstrated that recombinant DNA technology is a general purpose technology that can improve productivity across many sectors.
This section further explores how these three strategic logics function in the economic and military domain. For each logic, we describe the mechanics of the externality, provide examples of strategic assets, and differentiate our interpretation of the logic from related, influential concepts (cumulative to Van Evera’s “cumulative resources”; infrastructure to dual-use; dependency to Hirschman’s “dependence”). We conclude by highlighting the possible interactions between multiple logics, including scenarios in which assets are linked to multiple types of externalities or multiple logics come into conflict with each other.

Strategic Logic #1: Cumulative

The cumulative-strategic logic is underpinned by cumulative processes that entrench barriers to entry, a broad concept which covers long investment timelines, first-mover advantages, winner-take-all dynamics, learning-by-doing, etc. The potency of the cumulative effect can vary: a winner-take-all phenomenon, fueled by strong network effects, constitutes a strong version of the logic, while modest returns to scale generated by “learning by doing” evince a weak version of the logic.

The cumulative-strategic logic is relatively well-understood in the economic domain.26 Most markets do not yield substantial rents because interfirm competition moves the surplus to consumers. However, competition is weakened in cases of production characterized by cumulative effects, such as when returns only accrue after long time scales or risky bets, under strong economies of scale, and in the presence of other first mover advantages.27 Industries often identified as cumulative-strategic include semiconductors, computer software, telecommunications, and aircraft

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26 See Krugman 1986.
27 Kirshner 1998. On the subject of how the intervention of foreign governments affects the strategic calculus for certain industries, see Busch 2001.
As a byproduct of these cumulative processes, these strategic assets generate rents that accrue to the firms who were able to overcome the barriers.

Understanding how the cumulative-strategic logic applies to the military domain requires more work. We emphasize three applications. First, some military projects require long-term, high-cost investments that individual military branches and firms cannot bear. Brooks and Wohlforth explain: “Cumulated over years and decades, military spending can yield capabilities that are very hard to match even for a state with a lot of money to spend. This is especially true today, given the dramatically increased complexity and difficulty of both producing and using advanced weaponry.”

For the 19th and most of the 20th century, armed forces of first rank powers shared similar kinds of arms, but now only a few countries can afford complex weapon systems like surface warships and stealthy long-range bombers.

Second, cumulative dynamics manifest in the interaction between some military technologies and the organizations that produce them. For instance, A. Gilli and M. Gilli argue that the required technical knowledge to make stealth fighters has become increasingly organizational in nature, thereby limiting their diffusion. Since this organizational knowledge has accumulated in the collective memory of the U.S. military, rival nations cannot acquire it through licenses, stealing blueprints, or even kidnapping engineers. Third, the applications of the cumulative-strategic logic in the economic and military domains come together when firms in cumulative-strategic markets produce dual-use goods or when the production of military goods depends on firms that achieve economies of scale in nonmilitary markets.

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28 In the 1980s, the semiconductor, commercial aircraft, and telecommunications equipment industries exhibited large and increasing economies of scale as well as steep learning curves, which corresponded with strategic trade demands for the U.S. government to intervene on their behalf. Milner and Yoffie 1989.

29 Emphasis ours. Brooks and Wohlforth 2016, 18-19.

30 A. Gilli and M. Gilli 2019, 162-163.

31 Horowitz 2010, 24-65.

32 We thank Duncan Snidal for this point.
Lastly, it is important to relate our “cumulative-strategic” concept to Van Evera’s conceptualization of “cumulative resources.” Van Evera defines a cumulative resource as one that “helps its possessor to protect or acquire other resources,” and this concept has inspired research on the cumulativity of territory and conquest. He specifies that the cumulativity of a resource is a function of the utility of the resource for acquiring or protecting other resources as well as the cost of extracting the resource from its territory.

While Van Evera primarily conceives of cumulativity as a factor in an asset’s importance, we emphasize cumulativity as a type of externality. For instance, Van Evera asserts that uranium ore became more cumulative after the advent of nuclear weapons. Our framework does not preclude the valuation of an asset’s ability to enable the acquisition of other resources, but the fungibility of resources means that the vast majority of assets help their possessor protect another resource and qualify as cumulative under Van Evera’s conception. We do view uranium ore as becoming more important in the nuclear age, but we do not consider it to be cumulative-strategic as one nation’s investment in uranium did not lead to barriers to entry for other countries to acquire uranium.

Strategic Logic #2: Infrastructure

The second logic, which we call “infrastructure-strategic,” involves assets that generate large spillovers which cannot be privately appropriated by the initial innovators. These assets typically upgrade the national technological system, thereby benefiting other firms in the same industry or

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33 We thank Nuno Monteiro for pointing us to Van Evera’s concept of cumulative resources. Van Evera 1999, 105-116.
34 Ibid., 105.
35 Brooks 2005 and Rosecrance 2000.
36 Van Evera 1999, 106.
37 Ibid., 107.
38 This would fit under the “importance” bucket of our strategic formula
39 The dependency-strategic logic may have applied to uranium for some countries, but over time it was discovered that uranium ore was plentiful and relatively widespread across countries. Helmreich 1986.
related industries.\textsuperscript{40} In the context of this logic, the rivalrous variable measures the degree to which these spillovers are global (such as say basic advances in medicine), or are largely contained within national borders or amongst allies (such as transportation networks). Many technical advances, especially with increasingly rapid global diffusion, have global impacts, pushing out the technological frontier to the benefit of all parties.\textsuperscript{41} However, even in a world of increased cross-border diffusion of technology, the spillovers from many infrastructure-strategic innovations cluster geographically, differentially advantaging some nations over others.\textsuperscript{42}

Since this logic operates through interconnections that may benefit both the economic and military realm, infrastructure-strategic assets are often characterized as “dual-use.” Most of the time, economists are not trained to consider externalities in the national security domain, and military strategists do not focus on the effects of military technologies in the economic realm. Of the three strategic logics we highlight, the infrastructure-strategic logic is most helpful for illustrating the value of a framework that accounts for the strategic qualities of assets across both the economic and military domain.

Indeed, many dual-use technologies (e.g. computers) can be considered infrastructure-strategic, as actors oriented toward maximizing benefits in either the security or economic domain do not internalize the cross-domain spillovers.\textsuperscript{43} One particularly notable instance of spillover was the U.S. military’s investment in ARPAnet to secure the flow of information in the event of a

\textsuperscript{40} See Michalski 1991 and Teece 1991.
\textsuperscript{41} We thank Theodore H. Moran for this point. Whether technological knowledge spillovers are global or local has been much debated in the empirical economics literature. One analysis, Keller 2002, has shown that while local spillovers are still important, the extent to which knowledge spillovers decline with distance has fallen by 20 percent, partly due to the increase in foreign R&D by technology producers.
\textsuperscript{42} Borrus, Tyson, and Zysman (1986) write, “Because business and scientific communities, despite their international character, remain more tightly knit in a national than an international level, it is unlikely that the international exchange of scientific info can be a complete substitute for the erosion of a domestic base.” See also Busch 2001.
\textsuperscript{43} Dertouzos, Solow, and Lester 1989, 115.
nuclear attack, which resulted in the first internet.\textsuperscript{44} Flowing in the opposite direction, spin-ons from the commercial sector — which now leads military technology in most areas — to military applications have now become more important than spin-offs in the reverse direction.

Advancements in fiber optics, for instance, play an important role in the modern economy by transmitting data at high speeds, but they also have spin-on effects for national security by improving missile guidance capabilities.\textsuperscript{45} Evaluating the dual-use potential requires understanding how the connection between civilian and military assets is evolving.\textsuperscript{46}

In the economic domain, infrastructure-strategic assets are often foundational technologies that transform the outputs and production processes of a wide range of industrial sectors, and thus exert a profound effect on the competitiveness of national economic systems.\textsuperscript{47} Railroads, for instance, generated enormous positive spillovers by increasing labor mobility, enabling economies of scale for manufacturing, and expanding transportation of perishable products and natural resources.\textsuperscript{48} Additionally, the semiconductor industry is often characterized as providing extremely large spillovers to downstream electronics applications, though some scholars have questioned if private actors actually under-invest in this industry.\textsuperscript{49}

In the military domain, the infrastructure-strategic logic characterizes technologies that can upgrade a wide range of military capabilities but are underappreciated due to entrenched organizational interests and lack of coordinated investment. National security organizations primarily

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\textsuperscript{44} U.S. military planners did not initially view ARPAnet as an infrastructure-strategic technology with possible spillover effects, as the internet was more a product of happenstance than intentional strategy.

\textsuperscript{45} Samuels 1994, 30.

\textsuperscript{46} The connection between some civilian and military assets are becoming more tenuous (e.g. civilian-aircraft and military-aircraft technology). OTA 1988, 30.

\textsuperscript{47} Dosi et al. 1989.

\textsuperscript{48} These effects have been empirically demonstrated in a variety of country contexts, including China (Banerjee et al. 2012); India (Donaldson 2018); America (Donaldson and Hornbeck 2006).

\textsuperscript{49} One econometric study found that there are robust appropriability conditions for R&D spending by semiconductor firms, meaning firms are able to capture most of the benefits from spillovers. Levin and Reiss 1988. See also Moran 1990, 87.
pursue their mission, which contributes to but is not wholly encompassing of the national interest, so they may under-invest in assets that increase the effectiveness of other organizations.

The radar [1930-1945] is a representative example. Despite having an early lead in developing radars more advanced than the British, Germany failed to realize the radar’s potential due to interservice rivalry. The German navy had started work on radar in the early 1930s but did not share any information with the German air force. German leaders also failed to establish a liaison mechanism between the radar units, the fighter units, and the command organization. As a result, when the British conducted a bomber raid on Germany two days after declaring war, German radar detected the bombers, but no fighters were sent out to intercept them.50 In contrast, the British rapidly integrated radar into a battle-ready air defense system — a process that involved standardizing updates on the number, course, and heading of enemy aircraft — that took full advantage of its infrastructure-strategic attributes.51

**Strategic Logic #3: Dependency**

Our third logic, “dependency-strategic,” distills ideas from the substitutability camp into the language of externalities. Our framework highlights relations of dependence that are not internalized by private actors, namely economic transactions involving goods and technologies where a concentration of foreign suppliers imposes a negative externality for the importing state, represented by the potential economic and security costs of being cut off from accessing these items.52 Individual firms do not fully internalize the downside of a cut-off for the nation’s economy or military, for which continued access to these dependency-strategic assets is at risk due to the lack of substitute goods and alternative suppliers. It is important to differentiate dependency-strategic assets from

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50 Lorber 2016, 55-56.
51 Rosen 1988, 143-149.
52 Many of these ideas were introduced in Hirschman 1945.
advanced technologies further downstream, such as nuclear weapons and stealth technology, which states do not need to purchase on an ongoing basis.

Dependency-strategic concerns affect both the military and economic domains. At the military end, there are dependency-strategic goods that enable important military functions. For instance, the Germany military’s supply of explosives was severely hampered in the lead-up to World War I due to the British blockade, which cut off German access to nitrate exports from Chile, producers of almost 80 percent of the world’s nitrates.\(^5\) In the lead up to World War II, the U.S. Army and Navy Munitions Board created a list of 42 strategic and critical minerals necessary for the war effort, which included chromite and manganese; today, the U.S. National Defense Stockpile stores 21 materials for purposes of national defense, including quartz crystal and hot-pressed beryllium metal powder, to preclude a “dangerous and costly dependence” on foreign sources of supply in times of national emergency.\(^5\)

On the other end of the spectrum, certain dependency-strategic assets fuel functions that are primarily economic. In the postwar period, Japan took a techno-nationalist approach toward securing such goods, even at the expense of undermining important political-military relationships. Japan’s Ministry of International Trade and Industry (MITI) implemented \textit{kaihatsu yunyu} programs to secure resource production networks for the steel and aluminum industries through investing in overseas smelters when domestic smelting became uneconomical.\(^5\) Currently, the U.S. government also maintains a list of minerals critical to economic well-being.\(^5\)

\(^5\) Had it not been for Germany’s development of synthetic nitrogen, Germany may have lost the war much earlier. McNeil 1982, 79-102.

\(^5\) For a history of strategic stockpiling in U.S. policy see National Research Council 2008.

\(^5\) Heginbotham and Samuels 1998, 201; Wilson 2013.

\(^5\) One of the 23 strategic minerals is platinum, for which 90 percent of production since 1990 has come from two countries: Russia and South Africa. Zientek et al. 2017.
Some goods are critical for both economic and military processes. Oil, the “strategic commodity second to none,” is the classic case of such an asset.\textsuperscript{57} Before and during World War I, the British set fire to oil fields and the Germans torpedoed freighters, all to prevent the other side from powering their military industries.\textsuperscript{58} Additionally, because oil is crucial for industrial economies and consumed in such quantities that it is difficult to stockpile, countries have deployed the “oil weapon,” i.e. threatened to or actually cut off oil shipments to other countries, as a tool of economic coercion.\textsuperscript{59}

Our view of dependency-strategic assets builds upon Hirschman’s concept of dependence, which he defines broadly as “that part of a country's well-being which it is in the power of its trading partners to take away.”\textsuperscript{60} Hirschman centers his analysis of dependence on the concentration of a country’s aggregate imports and exports to shed light on bilateral channels of influence. Expanding on this analysis, our framework examines the concentration of suppliers for specific goods; dependency-strategic assets highlight not just bilateral power relations but also situations of dependence on suppliers that are politically unstable or vulnerable to natural disasters.

The Logics in Combination

While we have largely analyzed these strategic logics in isolation, in any given case these logics can overlap, complementing, attenuating, or complicating each other. States should pay especially close attention to those technologies and goods that exhibit multiple strategic logics. First, if multiple logics are operative, then the asset is, all else equal, more strategic. Second, multiple logics may call for a diverse set of policy responses to address each externality, complicating the policy problem.

\textsuperscript{57} Yergin 1990, 163.
\textsuperscript{58} Ibid., 151-168.
\textsuperscript{59} Licklider 1988, 205-226.
\textsuperscript{60} Hirschman 1945, 18-19.
Strategic assets can be characterized by multiple complementary logics (Figure 1). Oil, for instance, is the prototypical strategic asset because it activates each of these strategic logics in a powerful way. Oil is *cumulative-strategic*, in that it gives rise to a valuable industry characterized by an oligopolistic global market structure. It is *infrastructure-strategic*: its integration leads to a broad upgrading of economic and military systems, for which no sub-state actor has full incentives to adequately provide. It is *dependency-strategic*: it serves as a critical flow input which is vulnerable to being cut-off.

Chips are another asset that has exhibited all three of our framework’s logics.\(^{61}\) For large portions of its history, the semiconductor industry has been defined by an oligopoly structure, with only a few firms able to invest the high capital and R&D expenditures required to keep up with the fast-moving technical iterations (cumulative-strategic). In addition, investments in integrated circuit development generated infrastructure-strategic spillovers through inspiring new products and benefitting productivity growth in the entire electronics value chain, feeding into advances in computers, machine tools, robots.\(^{62}\) Finally, chips are dependency-strategic in both domains. Only a small group of foundries can design and/or fabricate the microchips that power a range of crucial military platforms, including aircraft, electronic warfare systems, and radar. These foundries also

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\(^{61}\) Chips refers to integrated circuits, which constitute a large segment of the semiconductor industry.  
\(^{62}\) Crawford 1993, 53.
make the chips that are a critical input across the information communications technology infrastructure in the economic domain, one comparable to iron and steel in historical importance.\textsuperscript{63}

A second type of relationship arises when the logics tradeoff with each other. States seeking to capture a positive externality from one strategic logic may expose themselves to a negative externality from another strategic logic. Churchill encountered such a tradeoff between the infrastructure-strategic and dependency-strategic logic when deciding whether to convert the British navy to oil-burning ships. On the one hand, oil-powered ships presented a significant upgrade in operational efficiency, speed, and radius of action, which would provide a spillover boost to the range and capabilities of the entire military. On the other hand, the transition from ships powered by steam coal (abundant in British mines) to oil (appreciable quantities only existed abroad) would also make the navy reliant on oil imports from distant countries.\textsuperscript{64}

These tradeoffs underscore the difficulties faced by policymakers concerned with industrial policy, economic statecraft, and grand strategy. Whereas Churchill confronted a tradeoff rooted in a single asset, Qian Xuesen, the “father of China’s space program,” encountered another tradeoff between two assets that exhibited different strategic logics (cumulative-strategic and infrastructure-strategic).\textsuperscript{65} In the 1960s, amidst debates over whether China’s strategic weapons policy should prioritize building aircraft bombers or missiles in the 1960s, he advocated for the latter, arguing that developing missile materials would produce positive spillovers that would broadly benefit China’s development of aviation systems, which were also a government priority at the time. Aircraft bombers, which exhibited the cumulative effects of higher thresholds for design and production and barriers to entry, necessitated a much longer learning curve for China’s defense industrial base. One

\textsuperscript{63} Yoshitomi 1991, 19.  
\textsuperscript{64} Yergin 1990, 156.  
\textsuperscript{65} Feigenbaum 2003, 34-35.
could argue that the effects of China’s decision to invest in missiles lingers on today, as China’s defense base has caught up to the most advanced militaries in missiles but not in aircraft engines.\(^6\)

\(^6\) Brooks and Wohlforth 2016, 38.
Part III: Applying the Three-Logic Framework

We apply the three-logic framework to evaluate how policymakers made *ex ante* assessments of strategic assets in two historical cases: the Avon 2 engine in the 1950s and the U.S.-Japan technology rivalry in the late 1980s. Revisiting postwar debates over the strategic importance of the aircraft industry differentiates our view of strategic assets from the oft-used heuristic of “military significance.” The U.S.-Japan case demonstrates how our framework can provide a landscape view for how policymakers assessed the candidate strategic goods and technologies in a particular period, with a focus on how U.S. policymakers mis-identified strategic assets.

Case 1 - Avon 2 Engine

The Avon 2 case contrasts our framework with the “military significance” heuristic, one of the most common intuitions used by policymakers and scholars for identifying strategic assets.\(^{67}\) The “military significance” heuristic is often expressed narrowly: an asset is strategic if (and only if) it is militarily significant. Under our framework, an asset is strategic only if it is significant in either the economic or military domain AND generates a rivalrous externality (e.g. follows one of our three logics). Thus, not all military assets are strategic, military assets are strategic for different reasons, and as we have shown above, many non-military assets are also strategic.

One of the most divisive issues for the U.S. and its Western European allies in the early postwar period was the question of which strategic assets should fall under the multilateral regime of export controls targeted at Communist bloc countries.\(^{68}\) The U.S. executive branch’s criteria for strategic importance was rooted in the “military significance” camp’s assumption that “items are

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\(^{67}\) Baldwin 1985, 212-213.

\(^{68}\) The regime was the Coordinating Committee for Multilateral Export Controls. While the main tension between the U.S. and its allies was over how restrictive the list of controlled assets should be (its allies wanted a more limited list), this section discusses a debate taking place within the U.S. policymaking sphere.
only strategic if they can be used for war, or converted for war, or processed into war-type goods.”

Others argued that an asset’s military utility was not an inherently strategic quality because trade operates on comparative advantage and money can be converted into making war-type goods. In this vein, Schelling pointed out that clothing was not necessarily less strategic than jet planes: “If the Russians are determined to consume clothes as well as aircraft, the strategic question is whether they get more planes by producing them at home and buying clothes abroad or by purchasing planes abroad and producing clothes.” For Schelling, even the “most peace-like of civilian goods [would] be ‘strategic imports’ to the Russians, if the Russians plan to consume some of them and find them difficult to produce.”

Schelling’s rebuttal illuminates some of the difficulties of categorizing an asset as strategic. It is also true that if the U.S. and its allies imposed an export embargo on aircraft at the time, the Soviets could get more planes by making them at home and buying clothes abroad since their aircraft industry was more efficient than the UK and German industry. But only examining efficiency metrics for the general aircraft industry overlooks the strategic characteristics of specific technologies, such as the Avon 2 Engine.

Our framework helps to illuminate how certain aircraft assets could be profoundly strategic in the 1950s, even while other aspects of the aircraft industry were less strategic than clothing. We first show why the Avon 2-powered aircraft deserved the strategic descriptor. Then, we highlight

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69 Schelling 1958, 500.
70 This point is made most forcefully in Baldwin 1985, 224.
71 Schelling 1958, 500.
72 Ibid., 500.
73 We use the engine horsepower of the aircraft produced per employee as a proxy for efficiency. Khanin 2003, 1189. Although we could not find a comparable statistic for clothing production, it is highly unlikely that the Soviet Union’s clothing industry was more efficient than its aircraft industry. The scarcity of adequate materials and centralized mode of clothing production prevented the Soviets from producing low-cost, high-quality clothing for their own citizens, let alone for a global market dominated by the Americans and the French. Amerian 2016, 65-82.
how the Avon 2’s cumulative-strategic affordances in both the economic and military realm can help explain the fierce Anglo-American disputes over the asset.

Designed by Rolls Royce and first incorporated into a jet aircraft by Britain’s de Havilland Aviation Corporation (which had launched the world’s first jet-powered commercial aircraft in 1952), the Avon 2 generated an *important rivalrous externality* for the United Kingdom. First, its *importance* in both the economic and military domain is easy to establish. The Avon 2, a high-thrust engine based on axial flow technology, served as the driver behind the bulk of Britain’s deterrent force — namely, long-range bombers able to threaten nuclear retaliation — and also promised enormous economic benefits in a major export industry.74 Second, it posed a cumulative-strategic *externality*: Moscow had not engineered its own engines due to the enormous technical cost and challenge; this first axial-flow jet engine was the cumulative product of years of Anglo-American collaboration.

Lastly, the degree to which the externality was *rivalrous* varied by the domain. The cumulative-strategic externality in the military domain — operationalized as the security of preventing rivals from perfecting a long-range bomber — was one that benefited the U.S. more, as America still remained outside the operational range of the Soviet’s most advanced bombers.75 In contrast, cumulative economic gains derived from the Avon 2 largely accrued to Britain, as British planners believed that De Havilland’s technological lead would snowball into a greater market share for future versions of their aircraft.76

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74 The UK’s Minister of Supply identified the aircraft industry as one on which Britain’s “future as a great nation may to no small extent depend.” Engel 2000, 46.

75 Ibid., 41.

76 Regarding the British lead in jets, one British Treasury official wrote, “If we do not here and now exploit it to the full we shall have lost, probably forever, a unique opportunity of capturing a fair share of the world trade in aircraft in which hitherto the Americans have had a virtual monopoly.” Ibid., 61.
This tension between the national beneficiaries of the military vs economic cumulative-strategic externalities was reflected in the bitter Anglo-American dispute over whether De Havilland should sell its aircraft in the civilian market. Selling the axial-flow powered jet aircraft would risk a vital piece of military technology;\textsuperscript{77} not selling would risk losing out on a key export industry to American competition. In 1952, the British announced that they planned to sell the axial-flow equipped aircraft to all non-communist countries, choosing to “risk perfect security for commercial gain.”\textsuperscript{78} The result was a fierce dispute with the Americans that lasted until 1954.\textsuperscript{79}

**Case 2 - US-Japan Tech Rivalry in the late 1980s**

While the case of axial flow-equipped jet engines demonstrates our framework’s utility for unpacking the distinct strategic logics operating for one specific technology, the U.S. response to Japan’s rise as a technological power reveals how our framework can check against distorted applications of the “strategic” label. In testing our framework against a flurry of high-level technological strategies that emerged in the late 1980s and early 1990s, we find that mis-applications in each of our three logics were rooted in overly broad categorizations of strategic technologies.\textsuperscript{80}

We choose to focus on the rationale behind technology assessments and policymaking efforts in the U.S. during the late 1980s for a variety of reasons. First, there is a rich literature and empirical record to pore through. The U.S. was facing a changing international landscape of power: as the Soviet Union neared its fall, Japan had emerged as a challenger to U.S. technological

\textsuperscript{77} These risks were rooted in precedent. The Soviets reverse-engineered Nene jet engine imports from the UK to power Mig-15s.
\textsuperscript{78} The Americans were concerned that limiting sales to non-Communist countries would not prevent those countries from attaining access via resales. Ibid., 45.
\textsuperscript{79} The dispute ended when the Soviets surprisingly demonstrated that they had developed engines more powerful than the Avon 2 without stealing the British engine. Though the conclusion to the axial-flow engine case was anticlimactic, it shows that the identification of strategic assets must be judged by the information known at the time.
\textsuperscript{80} The fuzziness of “technology” is a problem that haunts much of the relevant literature in the international relations field. One exception is Kitschelt 1991.
preeminence, sparking concerns over the U.S. ability to remain a leader in critical fields. From 1987-1991, representatives of government, industry, academia, and labor worked together to publish more than a dozen reports on critical technologies, and the period represented one in which technology policies were being considered in a more systematic and comprehensive way than in past eras. Second, there are echoes of the U.S.-Japan competition in the current period. China’s rising challenge to American technological dominance has raised similar concerns in U.S. policymaking circles about protecting strategic assets. Third, enough time has passed so that we can see whether the labeling of certain assets as strategic was prescient or not.

Three Logics Used in Debates over Industrial Policy

In many instances, U.S. policymakers and analysts invoked arguments that resonate with our three logics, with varying degrees of clarity and explicitness. In a widely-read text, Laura Tyson, a prominent voice for a “cautious activist” technology policy who later served as Chair of President Clinton’s Council of Economic Advisers, articulated the infrastructure- and cumulative-strategic logics, respectively: “In such industries...the returns to technological advance create beneficial spillovers for other economic activities, and barriers to entry generate market structures rife with first-mover advantages and strategic behavior.”

Fierce U.S.-Japanese disputes over supercomputers revealed the salience of the cumulative-strategic logic in the eyes of American policymakers. On the surface-level, the emphasis placed on supercomputers was a curious one since global annual sales of supercomputers were approximately $1.5 billion according to a 1992 estimate, a paltry sum compared to most other high-profile industries. However, U.S. decision-makers recognized that the production of supercomputers was

81 From a list of twenty technologies, the DoD’s critical technologies plan identified five technology groups critical to military superiority in which Japanese firms had the lead. U.S. Department of Defense 1990.
82 Mogee 1991, 24.
83 Tyson 1993, 3.
highly dependent on “learning by doing” in which experience developing previous generations transferred to developing the next generation, and early market share enabled the development of unique libraries of software. In this case, the logic was sound. By 1993, American firms were able to draw on these cumulative gains to dominate most markets, including 85 percent of the European public sector market — though they failed to penetrate Japan, which realized its industry could not compete without substantial protection.84

Additionally, the cumulative-strategic logic can explain why the U.S. was much less concerned about its steel industry, despite the fact that it was much larger than the supercomputer industry and was losing out in domestic markets to imports from Japan and Europe. In essence, technology crucial to producing steel had become easily diffusible alongside the maturation of the technology and the rise of a plethora of steel-producing states. The muted cumulative effects in this asset meant that the U.S. was more willing to make concessions on trade disputes over steel.85 

Generally, cumulative advantages fade as a technology matures, design parameters become standardized, and greater competition emerges through channels such as incremental refinement, distribution, and marketing.86

The infrastructure-strategic logic also shaped technology policy during this period. An influential Council on Competitiveness report published during this time period, titled “Gaining New Ground: Technology Priorities for America’s Future,” emphasized support for “critical generic technologies” that could potentially enable growth across a range of industries.87 Of these critical generic technologies, policymakers converged on microelectronics as a target for technology policy

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84 Matthews 1996, 130-134
85 Ibid., 140-142.
86 There are exceptions. In the domain of integrated circuits, maturity has been delayed by constant technological innovation, as exemplified in Moore’s law, which refers to an observation made by Intel co-founder Gordon Moore that the number of transistors on a chip doubles every two years while the costs are halved. Borrus et al. 1986, 104.
87 Council on Competitiveness 1991.
like the Strategic Computing Initiative. The justification for this choice was that advances in microelectronics provided “infrastructural support for all computer development, for they [made] all computer equipment faster, cheaper, and more reliable.”\(^{88}\)

Lastly, dependency-strategic concerns colored much of the policymaking surrounding strategic assets from the mid-1980s to the early 1990s. During this period, the U.S. government produced a total of sixteen different studies that assessed the globalization of U.S. defense production.\(^{89}\) Defense industrialists pinpointed America’s increased reliance on foreign suppliers for key components of weapon systems. For instance, Japanese companies such as NEC and Mitsubishi dominated the production of gallium arsenide (GaAs), a key material used in field effect transistors that enabled higher computing speeds and radiation resistance for missile guidance and radar.\(^{90}\)

Addressing these dependency-strategic concerns was not straightforward. With a defense technology base that increasingly relied on globalized, dual-use industries, the military faced a tradeoff between taking advantage of these infrastructure-strategic dual-use assets, or “going it alone” to avoid dependency-strategic risks. Indeed, the technologies where foreign dependence was most pronounced — e.g. advanced semiconductors, structural materials, and fiber optics — were also those driving innovation and qualitative improvements in critical military systems.\(^{91}\)

Blurry Conceptions of Strategic Assets in the Period

In other instances, U.S. policymakers and analysts failed to clearly evaluate strategic assets in this period. Based on her review of six reports that proposed lists of critical technologies,\(^{92}\) all of

\(^{88}\) Roland and Shiman 2002, 33.

\(^{89}\) Brooks 2007, 667.

\(^{90}\) Seventy-five percent of the GaAs material for field effect transistors were obtained from foreign sources, mainly Japanese companies. National Research Council 1985, 26.

\(^{91}\) At the time, the Office of Technology Assessment issued a series of annual reports that focused on this tradeoff: OTA 1989; OTA 1990; OTA 1991b.

\(^{92}\) This six reports: 1) U.S. National Critical Technologies Panel 1991; 2) Council on Competitiveness 1991; 3) U.S. Department of Commerce 1990; 4) U.S. Department of Defense 1990; 5) Computer Systems Policy Project 1990; 6) Aerospace Industries Association 1987.
which were published between 1987-1991, Mary Mogee found that the lists relied on broad
definitions of technology and different criteria, time horizons, and methodologies. In fact, Mogee
concluded, “Most of the reports involve little or no serious original research or data collection and
little or no guiding theoretical framework.”\textsuperscript{93} Using our framework’s three logics as a guide, we
outline three instances when overbroad conceptions of technology distorted American views of
strategic assets.

First, U.S. thinkers used the “high-tech” designation as a blanket label for strategic
industries, a fixation that Ostry and Nelson describe as “high-tech fetishism.”\textsuperscript{94} While some of the
“high-tech” sectors could be justified as cumulative-strategic (e.g. supercomputers, discussed above),
the “high-tech” designation was overly broad and produced flawed indicators of U.S.
competitiveness. For example, a 1986 report by the Department of Commerce (DOC) claimed that
the U.S. had a $2.6 billion trade deficit in high-tech industries, resulting in the creation of a potpourri
of councils, commissions, and institutes to study all the varieties of strategic technologies.\textsuperscript{95} But
when this high-tech trade deficit was measured in high-tech products rather than high-tech
industries, a deficit of $17 billion (1985-1988) turned into a surplus of $3.5 billion. In this case,
alysts had included trade in scales, cash registers, and similar products (which did not generate
cumulative-strategic externalities) in the indicator deficit because they fell under the DOC’s “Office
and Computing Machines” high-tech industry classification.\textsuperscript{96}

The emergence of the “high-tech” designation as a substitute for “strategic” also neglected
the degree to which other industries were being transformed by computers and microchips. From
the late 1980s the distinction between “high-tech” and “low-tech” industries was fuzzy, as segments

\textsuperscript{93} Mogee 1991, 37.
\textsuperscript{94} Ostry and Nelson 1995, 60.
\textsuperscript{95} Godin 2004.
\textsuperscript{96} Abbott III 1991.
of the textile, food-processing, healthcare, and construction industries were just as technologically advanced as the electronics and financial services sectors.  

In their attempts to apply the infrastructure-strategic logic, analysts treated biotechnology as an industry rather than a set of techniques that affect a wide range of industries. Biotechnology — largely oriented toward biomedical applications — was identified as a critical technology in four of the six influential technology reports reviewed by Mogee, but none of these reports assessed whether existing federal funding for biotechnology was sufficient. In fact, one OTA assessment recommended that Congress consider reducing federal funds for basic biomedical research given the success of existing private efforts and consider redirecting those funds to applications of biotechnology in other sectors such as agriculture, chemicals, and waste management. These recommendations underscore the need to clearly specify the contexts in which a set of techniques qualifies as infrastructure-strategic.

Finally, U.S. policymakers misdiagnosed the dependency-strategic logic in numerically controlled machine tools, marking a failure to zoom into the key technologies of a general sector as well as gauge the extent to which supply was concentrated in a particular country (our framework’s nationalization variable). In 1986, the U.S. government designated the entire industry of machine tools as strategic, negotiating a Voluntary Restraint Agreement (VRA) with Japan and other countries to limit the level of their machine tool exports to the U.S. for a period of five years. At the time, the general category of machine tools also included mature, standardized product models for which production was not concentrated in any particular country, limiting the salience of the dependency-strategic logic. In fact, new suppliers in Belgium, Denmark, Italy, and Spain were beginning to further reduce the U.S.’s dependence on Japan in some types of machine tools; however, the VRA

97 Dunning 2002.
98 Mogee 1991, 25-29.
99 OTA 1991a.
was counterproductive in this respect, restricting the expansion of these new suppliers. Instead, analysts should have focused their attention on specific sub-sectors of machine tools, such as grinders of ceramic and other non-metallic materials, where Japan dominated U.S. imports of these key sub-sectors.\(^{100}\)

Because of the tendency of interest groups and policymakers to deploy the “strategic” descriptor broadly, we have emphasized the false positives of the “strategic” label, but there were also false negatives in this period. For instance, military planners neglected dependency-strategic risks associated with rayon fibers. In November 1988, the American apparel company Avtex announced that it was closing down due to foreign competition, sending shockwaves through the U.S. military and space community, as Avtex was the only producer of rayon fibers critical to the production of missiles and rockets.\(^{101}\) Alternative sources could have been certified and other fibers could have been adapted into substitutes, but this process would have taken longer than the period of time the available supply of rayon would support production. While the U.S. government and aerospace industry officials eventually negotiated a deal to keep Avtex open, the case illustrates that the defense industry under-valued dependency-strategic concerns related to relying on sole-source supplies for key inputs.\(^{102}\)

One last note about how the above cases should be interpreted. Our framework elaborates three logics that can make an asset worth attending to. Our theoretical claim is that when these logics are operative, states who attend to the assets and adopt appropriate policies will gain in power and wealth. The reasons to believe this claim are that it is theoretically compelling, and it is the distilled core of what policymakers have been trying to realize. The above empirics do not evaluate

\(^{100}\) Moran 1990, 87-88.
\(^{101}\) OTA 1989, 33.
\(^{102}\) A concentration of foreign suppliers in a particular asset is not necessary for the dependency-strategic logic to be in play. For instance, relying on a sole-source domestic supplier also presents a negative externality because that supplier could experience disruptions in the form of natural disasters, cyberattacks, or accidents.
this claim. What they do is show how there was conceptual confusion around strategic assets, and thus if we take the prior theoretical claim as given, they show how conceptual clarity could have improved policy around strategic assets.
Part IV: Conclusion and Current Implications

We conclude by using the three-logic framework to take stock of candidate strategic assets in the current era, with a focus on advances in AI, widely viewed as economically and militarily transformative. As possible extensions of our framework, we highlight classes of strategic assets besides goods and technologies as well as strategic logics beyond the three in our framework.

Strategic Assets in the AI Era

First, big data platforms\textsuperscript{103} appear to be an asset that operates according to the cumulative-strategic logic. These platform technologies benefit from data-fueled network effects: the platform that gets a critical mass of users can use data science algorithms to leverage large quantities of data to optimize the user experience, attract more users, and generate more data.\textsuperscript{104} The possible result is a protective moat that prevents upstarts from entering these high-value industries. Alongside the digitization of more sectors of the economy, regulators have begun to explore options to restore competition with respect to digital platforms.\textsuperscript{105}

Many prognosticators assume that more data will enable big data platforms to inevitably multiply their existing advantages. For instance, high-definition street maps for driverless vehicles appear to be following winner-take-all dynamics in which autonomous car companies with the larger scale (e.g. ability to put more sensor-attached cars on the road) will win out. However, the cumulative effects of big data platforms are uncertain, as it is plausible that there are quickly diminishing returns with respect to economically valuable data, in which the cumulative advantages

\textsuperscript{103} Social media big data platforms include Facebook, Twitter, Tencent’s WeChat; consumer transaction big data platforms include Amazon, Alibaba, Walmart; health transaction big data platforms include CVS caremark.

\textsuperscript{104} We use the phrase “data science algorithms” rather than “AI algorithms” because up until at least 2015 most of the algorithms used on these big data sets (e.g. for Amazon’s recommender systems) were traditional "shallow" algorithms including e.g. linear regression or collaborative filtering that are definitely part of "data science" but usually not considered very central examples of "AI," especially as AI continues to be so connected to advances in "deep learning." We thank Luke Muehlhauser for this point.

\textsuperscript{105} Council of Economic Advisers Issue Brief 2016.
in AI services will hit a ceiling. Empirical evidence is essential to ground predictions. Google’s proven dominance in consumer digital maps, which accumulated through its large deployments of street-mapping cars around the world and its AI expertise, suggests that a similar story could unfold in the case of driverless vehicle maps.

The infrastructure-strategic logic is at the heart of much of the conversation surrounding AI. Recent work has identified AI as a general purpose technology, a class of technologies that lead to complementary innovation and can radically change the economic landscape.\textsuperscript{106} AI-enabled, smart manufacturing is one especially promising area for the infrastructure-strategic logic. Similar to how NC machine tools transformed a broad range of manufacturing industries, there is some empirical evidence that smart manufacturing could provide substantial industrial spillover effects.\textsuperscript{107}

Autonomous capabilities — which include unmanned underwater vehicles, autonomous unmanned aircraft, and systems to control rapid-fire exchange of cyber weapons and defenses — possess infrastructure-strategic potential in the military domain. A recent Defense Science Board Summer Study on Autonomy warns that the DoD may be missing out on significant positive spillovers: “While DoD is already embracing the value of autonomous capabilities, in both fielded systems and developmental programs, it has not yet adapted its enterprise processes to effectively support the rapid and widespread adoption warranted by the potential benefits.”\textsuperscript{108} The study’s drafters claim autonomy, fueled by advances in AI, has reached a “tipping point” in value, and that rapid transition of autonomy into warfighting capabilities is necessary for the U.S. to sustain its military advantage.\textsuperscript{109}

\textsuperscript{106} Brynjolfsson et al. 2018.
\textsuperscript{107} For example, see Min et al. 2019.
\textsuperscript{108} DSB 2016, 98.
\textsuperscript{109} \textit{Ibid.}, 98-99.
Lastly, the hardware necessary to train AI systems appears to be the most likely candidate dependency-strategic asset. By AI hardware, we refer to both chips, such as Nvidia GPUs, that are used to train machine learning systems, and those, such as Xilinx’s FPGAs, that are used to run machine learning algorithms on the end device. Provisionally, AI hardware meets some of qualifying conditions for the dependency-strategic logic: they feed into a broad range of machine-learning based services and their production is concentrated in a few firms.\textsuperscript{110} In fact, analysts are already theorizing about the effects of this strategic asset for U.S.-China technological competition over AI. As Tim Hwang writes, “The extent to which the U.S. is able to successfully deny China access to advanced computing power, and the extent to which China is able to develop it domestically or acquire it otherwise, remains to be seen.”\textsuperscript{111}

Concretely, demarcating what technological domains are most clearly non-strategic can reduce the risk of a broad technological rivalry from undermining cooperation in domains where it is in both actors’ interests to cooperate. For example, U.S. President Trump’s administration has adopted a zero-sum mentality in a wide range of trade and technological disputes, which has led to conflict with even allies over assets such as steel and aluminum,\textsuperscript{112} which our framework helps to reveal are not as strategic as other candidate assets.

Extensions of the Three-Logic Framework

One clear extension of the three-logic framework is to expand our analysis beyond goods and technologies. The scope of strategic assets could also include institutions (good university

\textsuperscript{110} The market for GPUs has been dominated by Nvidia (72.8% of the market share for GPUs, with the rest being controlled by AMD); the market for FPGAs has been dominated by a small set of fabless foundries (Xilinx led with a market share of 53% in 2016). Hwang 2018, 21.

\textsuperscript{111} Ibid.

\textsuperscript{112} Lynch 2018. We acknowledge that these tariffs may relate to other “strategic concerns,” including playing to domestic political constituencies. This paper is focused on what is strategic for national leaders of industrial great powers competing for relative wealth and security, so we do not claim to provide the singular, defining analytic lens for strategic assets.
systems), technological systems (mass-production), and people (German scientists captured by the U.S. after WWII who were instrumental in developing the U.S. rocket and missile industry).

The increased mobility of skilled migrants in today’s knowledge-based economy has elevated scientific and technological talent as a unique and distinct class of strategic asset. Interestingly, skilled migrants may exhibit positive-strategic externalities for both the receiving and the sending state. The positive externality for receiving states is obvious: they improve their stock of human capital without having to contribute to prior training and education. As the literature on “brain drain” versus “brain gain” has developed, recent studies have demonstrated that sending states may also benefit from return migration, access to business and trade networks, increased incentives for domestic enrollments in education, and remittances.

The externality is both rivalrous and substantial. The competition to win the “human capital accretion ‘sweepstakes’” is only intensifying, as evidenced by the liberalization of immigration policies targeted toward attracting high-skilled immigrants. Rosenblum captures the significance of these talent pools for states, “Now innovation is labor, and entire firms at the forefront of the information revolution exist for no purpose other than research and development...in contrast to the previous periods, access to skilled labor is the primary limiting factor that will define the geography and long-term distributive effects of the information revolution.”

In a second extension of the framework for strategic assets, economic structures and technological developments are bringing other strategic logics to the fore. In this section, we highlight the “poisoned chalice-strategic logic.” In contrast to the threat model for the dependency-strategic logic that involves being cut off from the asset, the “poisoned chalice” threat model is one

113 The number of high-skilled migrants (those with a tertiary degree) residing in OECD countries has increased nearly 130 percent since 1990. Kerr et al. 2016, 83.
114 Docquier and Marfouk 2006
115 Adamson 2006
116 Rosenblum 1001.
of being poisoned because of someone else’s access to the asset. In this case, upstream parts and components of key industries may become increasingly strategic, as states are exposed to supply chain threats such as defective parts and hardware hacks.

The globalization of supply chains and the increased number of components in military platforms has exposed states to the poisoned chalice-strategic logic.\textsuperscript{117} For instance, the number of parts required for a combat aircraft has risen from hundreds of components in the 1930s to around 300,000 in the 2010s.\textsuperscript{118} One concern is malicious behavior on the part of foreign subcontractors, especially if they are following direct instructions from a hostile government or military.\textsuperscript{119}

This risk is accentuated since officials from both Lockheed Martin and Boeing have said it would be “impossible” for any U.S. defense contractor to identify the full range of subcontractors for a weapons platform due to the complexity of supply chains and sheer number of foreign suppliers. One Boeing official has estimated that the defense contractor’s supply chain for a weapon system could include up to 2,000 foreign subcontractors.\textsuperscript{120} Counterfeit parts can also disrupt the DoD supply chain and damage weapon systems integrity. After setting up a fictitious company and buying military-grade electronic parts that could enter the DoD supply chain, the U.S. Government Accountability Office found that vendors often provided counterfeit and deficient goods; some were even willing to supply parts that do not technically exist.\textsuperscript{121} Lastly, datasets can be “poisoned” to

\textsuperscript{117} The dependency-strategic logic and poisoned chalice-strategic logic are closely related. If the U.S. defense industry had a more reliable domestic foundry capacity (i.e. it was less exposed to dependency-strategic logic), it could limit poisoned-chalice concerns to some extent. However, while the concentration of foreign suppliers is a crucial factor for determining the risk of dependency-strategic concerns, the threat of the poisoned-chalice logic only requires the existence of vulnerabilities in supply chains, which can occur regardless of the concentration of foreign suppliers.

\textsuperscript{118} A. Gilli and M. Gilli 2019, 150.

\textsuperscript{119} Similar concerns have surrounded the purchase of hardware from the two largest Chinese telecommunications equipment manufacturers, Huawei and ZTE.

\textsuperscript{120} These statements from Boeing and Lockheed Martin officials come from Brooks 2007, 671-672.

\textsuperscript{121} The U.S. GAO received responses from 396 vendors, of which 334 were located in China, 25 in the United States, and 37 in other countries, including the United Kingdom and Japan. See U.S. GAO 2012.
attack the integrity of AI that are trained on them, such that even a single inserted (correctly labeled) observation can produce a “backdoor” that can later be exploited.\textsuperscript{122}

Final Considerations

Most studies of economic statecraft and defense industrial policy concentrate on the actors, the strategies, and the effects involved with the deployment of economic power for strategic gain. Significantly less emphasis is placed on the objects themselves — the strategic assets which are often the target of military competition and foreign economic policy. The fundamental contribution of this article is toward resolving a tension in the international landscape today: even as nations are increasingly concerned about building up their advantage in strategic goods and technologies, much more work needs to be done to understand the underlying logic of what makes an asset strategic.

It would be a mistake to make the leap from the identification of a particular good or technology as strategic to the implementation of industrial policy targeted at that good or technology. Cost overruns, wasteful rent seeking, and crowd-out from “picking winners” all contribute to “government failure,” which could outweigh the benefits of correcting market failures.\textsuperscript{123} Capturing the view of many scholars, Grübler writes that he is “personally skeptical about technology 'planning', forecasting, and selection by central authority.”\textsuperscript{124} Therefore, mapping the logic behind strategic goods and technologies is only a starting point.

Still, our effort to bring conceptual rigor to the discussion of strategic assets is a prerequisite to effective strategy. Consider one of the problems covered throughout the article: the globalization of the U.S. defense industry. Heavy dependence on an asset provided by a diversified base of foreign suppliers may not pose as much risk as moderate dependence on an asset provided by a

\begin{thebibliography}{99}
\bibitem{122} Shafahi et al. 2018.
\bibitem{123} This literature is concisely summarized in Kirshner 1998. An extreme example of implementation costs is conquest.
\bibitem{124} Grübler 2003, 6.
\end{thebibliography}
concentrated group of foreign suppliers.\textsuperscript{125} In this way, understanding how the dependency-strategic logic functions can clarify how to characterize the threat posed by the globalization of supply chains to America’s defense base.

Our framework does clearly call for more attention to identifying strategic assets through careful measurements. While the difficulty of identifying strategic assets is exacerbated by the influence of special interest groups, reasonable measures to identify strategic assets do exist, and, at the very least, they function as improvements over relying on gut feel. Regarding infrastructure-strategic assets, for instance, empirical studies have measured the appropriability of returns from private R&D for high-tech industries.\textsuperscript{126} Additionally, defense industrial strategists concerned with dependency-strategic goods can draw on measures of oligopoly strength, such as the “4/50 rule of thumb” which tries to ensure that no four companies or countries supply more than 50% of the market for key systems.\textsuperscript{127}

Our framework suggests many directions for future research. One of the most pressing issues, which has plagued analysis of strategic goods in past periods (including, as this article as shown, the late 1980s and early 1990s), is grasping the most useful levels of specificity for referring to goods and technologies. This issue has even featured in previous international disputes over economic sanctions. For instance, amidst a disagreement over the specifications of COCOM controls, the U.S. definition of technology sharply differed with that of Europe and Japan. The U.S. argued that the definition of technology should include “knowledge, skill, and information, as well as industrial goods,” whereas Europe and Japan argued for a narrow definition of technology as “machinery and transport equipment.” Analysts frequently use the term “technology” to refer to

\textsuperscript{125} Moran 1990.
\textsuperscript{126} Levin and Reiss 1988.
\textsuperscript{127} This rule is detailed in Moran 1990.
broad concepts, fields of study, processes, a cluster of equipment and processes, as well as machinery and equipment.

Fred Halliday called international relations the capstone discipline of the social sciences in part because the discipline is tasked with integrating concepts from all the other sciences. An economist may identify strategic assets as the civilian technologies of greatest economic importance; a military planner may think of strategic assets as those that are most essential to military operations; a historian may understand strategic assets as those that have had the most significant effects in shaping the development of society. Our paper offers a framework for how a grand strategist should conceive of strategic assets.
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