LOSS OF THE INDUSTRIAL COMMONS IS AN EXISTENTIAL THREAT TO U.S. PROSPERITY

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The United States has lost its capacity to innovate and mass produce emerging hardware technologies. After five decades of offshoring production, the United States is dependent on foreign production across virtually every advanced manufacturing industry, including industries critical to the nation's security and health, such as medical equipment and pharmaceuticals. Manufacturing has been considered to be a low-value activity, ignoring the tight linkages between manufacturing, product innovation, and the ability to consistently add value and control full value chains over the long term. As a result, the United States has lost its industrial commons, the collective research and development (R&D), engineering, and manufacturing capabilities that sustain innovation in physical products.[1] Because the tight linkages between actual production and new product innovations have been lost, the long-held strategy to "invent here, manufacture there" is fast becoming "innovate there, manufacture there." The United States may still be one of the most inventive countries but no longer the most innovative, at least in hardware. The result is a smaller, less innovative manufacturing sector that no longer has the capacity or resiliency to meet a nationwide health crisis and is no longer capable of supporting the nation's defense ambitions and the wealth creation needed to remain a global superpower. Without a national manufacturing strategy and long-term, sustained investments to rebuild its lost capabilities, it is unlikely the United States will be in a position to establish, let alone lead, the hardware industries of the future. U.S. global leadership and the long-term well-being of Americans will suffer.

The coronavirus pandemic, by exposing the costs of our weakened industrial base to the nation, should provide the impetus to policy makers to take significant and effective action. Establishing a new, cabinet-level federal agency will demonstrate that the nation is serious about restoring manufacturing. Such an agency will have long-term consistent funding to develop and implement a national manufacturing strategy, work with states and the private sector to rebuild the industrial commons, ensure that the U.S. generates returns from its massive investments in R&D, and regains global leadership in the manufacturing industries of the future.

HOW DID WE GET HERE?

U.S. manufacturing competitiveness has been a concern at least since the 1980s, a result of changing global competition and evolving management theory and practice. Beginning in the 1970s, the post-war consensus in which management worked with labor to share the fruits of domestic production began to break down. Opportunities to shift labor-intensive production offshore in industries such as textiles, apparel, and furniture emerged as other countries rebuilt industrial capacity and governments, led by the United States, worked to liberalize global trade.[2]

At about the same time, shareholder primacy theory—the idea that shareholder value should be the primary (even only) goal of corporate managers—was promoted by consultants and academics such as Milton Friedman.[3] Rather than maintaining the longstanding social contract with labor, cost-cutting and profitability became paramount objectives.

The easiest way to cut costs was to cut jobs, and the easiest way to do that was to move production offshore. Starting with low-skill, high-labor content industries such as apparel, American manufacturers began moving production facilities to Asia and Latin America, especially Mexico. Consumer electronics soon followed. For example, American color television manufacturers such as RCA and Zenith shifted production to Asia because assembly was labor intensive, requiring little skill, and American firms believed the industry had reached maturity so innovation was less of a competitive factor than low cost. Meanwhile, Japanese producers such as Sony continued to innovate, in both the product and production process, switching to solid state chassis, in-line tubes, early use of integrated circuits, and automation.[4] This early shift in the geographic locus of television production to Asia laid the groundwork for future innovations, such as flat screens, and helps to explain why U.S. producers missed this market. By moving production offshore, U.S. producers lost manufacturing and product design and engineering skills needed to keep pace with foreign competitors. Similarly, in the emerging semiconductor industry at the time (1970s), packaging and testing, another low-skill, labor-intense process, moved offshore, almost from the very beginning of the industry and remains offshore to this day.[5]

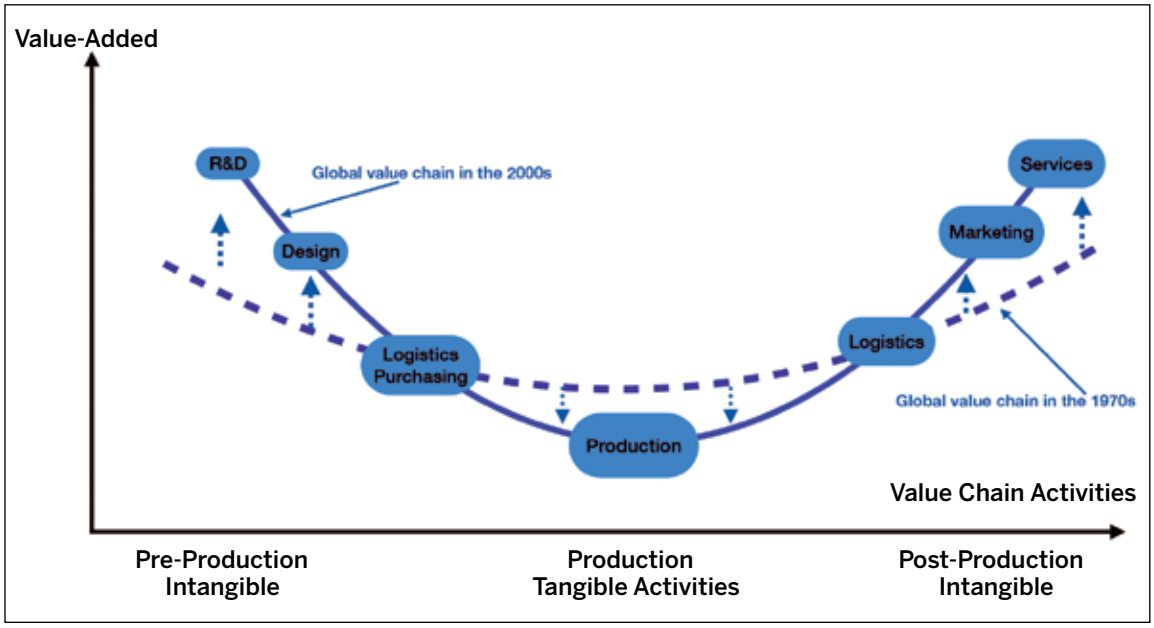
Although the full extent of this initial wave of offshoring is difficult to quantify, one partial indicator is the growth of Section 806 and 807 imports.[6] These rose steadily from $953 million in 1966 to $36.5 billion in 1986.[7] These figures do not include imports by U.S. companies containing only foreign parts or production by contract manufacturers. They also exclude intra-company trade, which was more than one-third of U.S. trade in the late1970s-early 1980s.[8] Other data indicate the extent to which U.S. production moved offshore in the late 20th century:

- In 1985, U.S. companies employed more than 35,000 workers in the Malaysian electronics industry.
- By 1986, Taiwan had a $15.7 billion trade surplus with the United States, and its largest exporters were American companies, including General Electric, IBM, and HP.
- The number of maquiladora factories in Mexico rose from 450 with 70,000 workers in 1974 to 1100 with 300,000 workers in 1986; U.S. companies operated 865 of those.[9]
- In 1973, manufacturing comprised more than 86 percent of U.S. industrial production. By 1982, it had fallen to 71 percent, and in 2014 was only 68 percent, before climbing to about 75 percent in 2019.[10] Industries ranging from furniture to computer and electronic products follow this pattern. Only chemicals has achieved a significant increase, growing from 9 percent in 2000 to 13 percent in 2019 due to the boom in U.S. oil and gas production.[11]

THE EROSION OF THE U.S. INDUSTRIAL COMMONS AND INNOVATION CAPACITY

Success with offshoring manufacturing during this period created an American management mantra that continues to drive production decisions. Despite a few respected voices to the contrary,[12] American managers (and policymakers) determined that manufacturing is not critical to competitive success. As long as R&D, product design, engineering, marketing, and service remained in the United States, manufacturing location does not matter. “Invent here, manufacturer there” was considered the key to success. Production should be done to minimize costs. Common in management classes, this reasoning is often illustrated in the “Smiling Curve” diagram (Figure 1). Activities considered to be high-value are concentrated on the sides, while

FIGURE 1. The Smiling Curve



Source: "Interconnected Economies Benefitting from Global Value Chains," OECD 2013.

low-value activities, production and logistics, are in the middle. Well-managed companies should focus on the high-value activities. Production, regardless of product value or sophistication, should be done wherever the costs are lowest. In many cases, leading American management consultants advised companies to minimize costs wherever practicable, even for high-value activities, contributing to the shift of R&D and some services offshore.[13]

Initially, the common assumption, at least among policymakers, was that U.S. companies would move low-value, unsophisticated production offshore, retaining high-value, research-intensive, and innovative manufacturing. But the inexorable shift of suppliers and factories abroad meant that the skills, experience, and hands-on knowledge that can only be gained from inside factories gradually moved offshore, too.[14] And as that knowledge and those skills developed in Asia, U.S. companies found it both easy and unavoidable to produce even high-value goods abroad. Some economists recognized the importance of manufacturing in maintaining the capability to innovate and produce high-value technology, but the repercussions of losing manufacturing knowledge were not generally recognized and were overwhelmed by the clear, compelling financial benefits.[15]

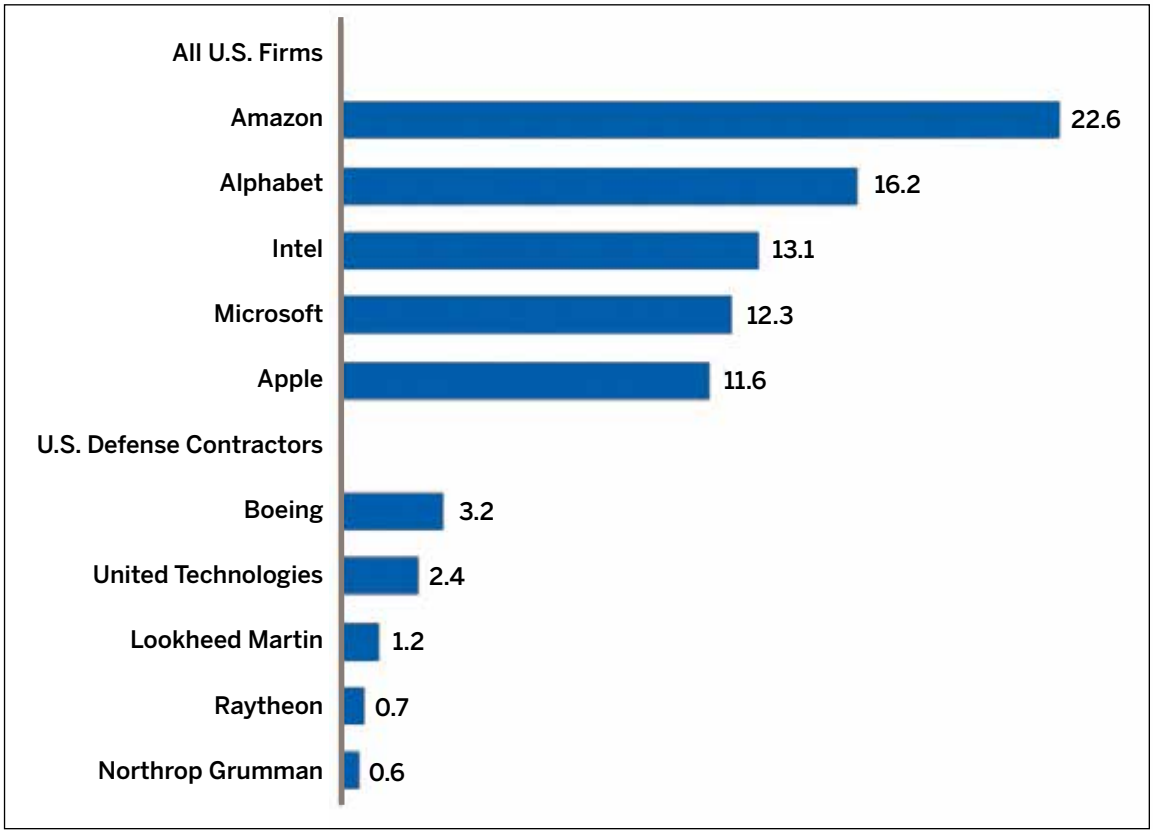
With this management practice firmly entrenched, the opportunities presented by China as a low-cost producer were overwhelming. Although China began to open to foreign investment in the 1980s in Special Economic Zones, the role of China as a source of manufactured goods, and the preferred location for American manufacturers, accelerated in 2001 when China joined the World Trade Organization (WTO).[16] But from the outset, China's development ambitions were clear. Not content to remain a low-cost producer of relatively low-value products, China learned from its Asian neighbors. Host governments in Taiwan, Korea, and other countries demanded that U.S. firms use more domestic content, support local suppliers, transfer more advanced technology, and form joint ventures with local companies. These policies enabled domestic producers to move up the value chain, creating formidable competitors and establishing a successful playbook for economic development. Particularly in these so-called "Asian Tigers," a combination of domestic and foreign direct investments, supportive government policies, fierce domestic competition, and a strong focus on exports enabled local companies to focus on

sophisticated, high-value products.[17] In industries as diverse as furniture, televisions, photocopiers, and microprocessors, contract manufacturers became competitors. Companies such as Samsung, Hyundai, and TSMC are global leaders, largely built on their manufacturing prowess.

In the case of China, for instance, all foreign automotive producers were required to form joint ventures with local companies.[19] Other requirements, such as domestic content, technology transfer, and forced licensing of intellectual property (IP) enabled China to increase its high-value production capabilities and establish comprehensive supply chains. China has successfully created unsurpassed ecosystems of industrial production encompassing the entire value chain from raw materials to final product. In many advanced industries, Chinese firms have mastered the ability to scale complex product designs into efficient mass production.[19]

Increasingly sophisticated production, comprehensive supply chains, and growing science and engineering skills have also allowed China to become an attractive location for R&D, especially for American companies that have come to view R&D as a cost to be avoided rather than an investment in the future.[20] U.S. companies have been most aggressive in moving R&D to China, accounting for more than $18 billion and over 40 percent of all foreign R&D investments in China in 2015.[21] Not only has China's business spending on R&D virtually matched the United States—$397 billion vs $384 billion—but also as a percentage of gross domestic product (GDP) the United States has fallen behind South Korea, Japan, and Germany.[22] U.S. tech companies now far outspend U.S. defense contractors on R&D (Figure 2).[23] Driven by cost reduction, American corporate laboratories now rarely address long-term research questions, focusing instead on short-term problem solving and incremental product development.

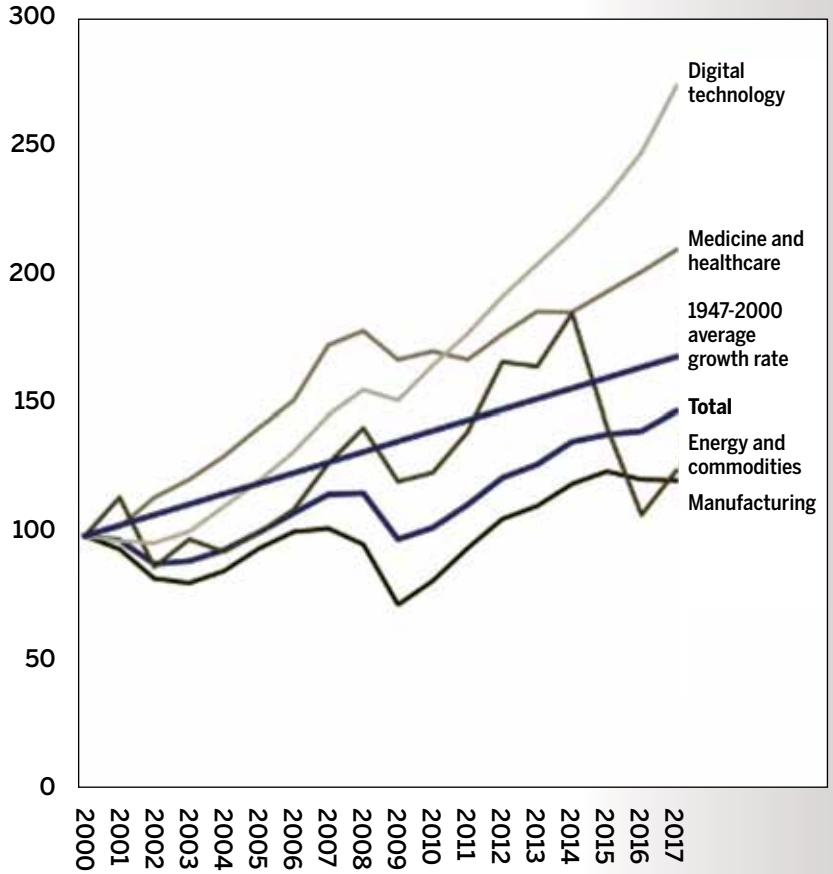
FIGURE 2. R&D Budgets in 2018 ($ Billion)



The impact of China's full admission into the global trading system, combined with shareholder primacy driving American corporate decision-making and the widespread conviction that the United States should evolve into the next stage of economic development—the post-industrial economy—has been transformative and jarring. Evidence includes:

- U.S. manufacturing is now only 11 percent of GDP, compared to nearly 27 percent in 1990, and 22 percent and 21 percent in Germany and Japan respectively.
- The number of U.S. manufacturing establishments dropped from 390,000 in 1996 to 290,000 in 2017, reflecting the loss of suppliers as final production has moved offshore.[24]
- The number of manufacturing jobs has plummeted, largely due to the impact of trade. According to the Economic Policy Institute, the trade deficit with China has displaced 3.7 million jobs since 2001.[25]
- Capital investment in domestic manufacturing has been low and stagnant (Figure 3).[26]
- Without investment, labor productivity in manufacturing has stagnated, actually declining since 2010 (Figure 4).[27]
- In many industries, the U.S. has lost control of the means of production, the machine tools and advanced processing equipment that drive innovation in manufacturing processes. Only in semiconductor processing equipment does the U.S. maintain a large share of the global market, around 50 percent, but even here, the most advanced extreme ultra-violet photolithography machines are produced by a Dutch firm, ASML.[28]
- The U.S. trade deficit has reached record levels, even in medium and high-technology products that should still be a source of competitive advantage and where the United States has fared worse than other advanced economies (Figures 5 and 6).[29]
- By one estimate, U.S. manufacturing value added per capita grew less than one percent annually between 1980 and 2010.[30]

FIGURE 3. Change in U.S. Fixed-Cost Investment in Private Nonresidential Fixed Assets by Type



While the statistics paint a dire portrait, they don't reveal worrying conditions in individual industries in which the United States is almost completely dependent on foreign, especially Chinese, suppliers. One prominent example is fifth generation (5G) telecommunications equipment. The leading role of Huawei as a supplier of the full range of 5G equipment has raised security concerns in Washington, strained relations with European allies, and forced high-level discussions with U.S. and foreign technology firms on an appropriate response. The U.S. military is also concerned. In 2015 Army General John Adams wrote, "Our almost complete dependence on China and other countries for telecommunications equipment presents potentially catastrophic battlefield vulnerabilities."[31]

FIGURE 4. Dramatic Decline in Manufacturing Productivity Growth

The national health emergency revealed other critical dependencies on foreign suppliers. Pharmaceuticals are a prominent example, especially considering that it is a knowledge-intensive industry that receives substantial financial benefit from federal R&D spending by the National Institutes of Health. Consider that

- Over 70 percent of the active pharmaceutical ingredients (APIs) used in the U.S. market are produced overseas, with over 30 percent sourced from India and China.[32]
- Over half of the factories producing final dosage form medicines for the U.S. market are outside the United States.[33]
- Three commonly used antibiotics—azithromycin, ciprofloxacin, and piperacillin/tazobactam—depend on ingredients manufactured only in China.[34]
- Nearly half of the U.S. supply of hydroxychloroquine is made in India, as are most of the required APIs.[35]

Another noted example is the Kindle e-reader. An analysis by Harvard Business School professor Willy Shih concluded that the Kindle cannot be manufactured in the U.S., despite its defining technology, electronic ink, having been invented here.[36]

These examples, as well as the other foreign dependencies in medical devices and personal protective equipment (PPE) point to the alarming condition of the U.S. manufacturing sector. Across multiple industries, the U.S. has lost its industrial commons, the collective R&D, engineering, and manufacturing capabilities that sustain innovation in physical products.[37] Outsourcing production over multiple decades has left the country without the means or ability to innovate, let alone produce, the next generation of high-technology products. Further, a recent study found that foreign competition "robustly curtails U.S. patent production."[38] The country has lost suppliers, skilled trades, and the product and process design and engineering knowledge

FIGURE 5. Trade Balance of High R&D Intensive Products

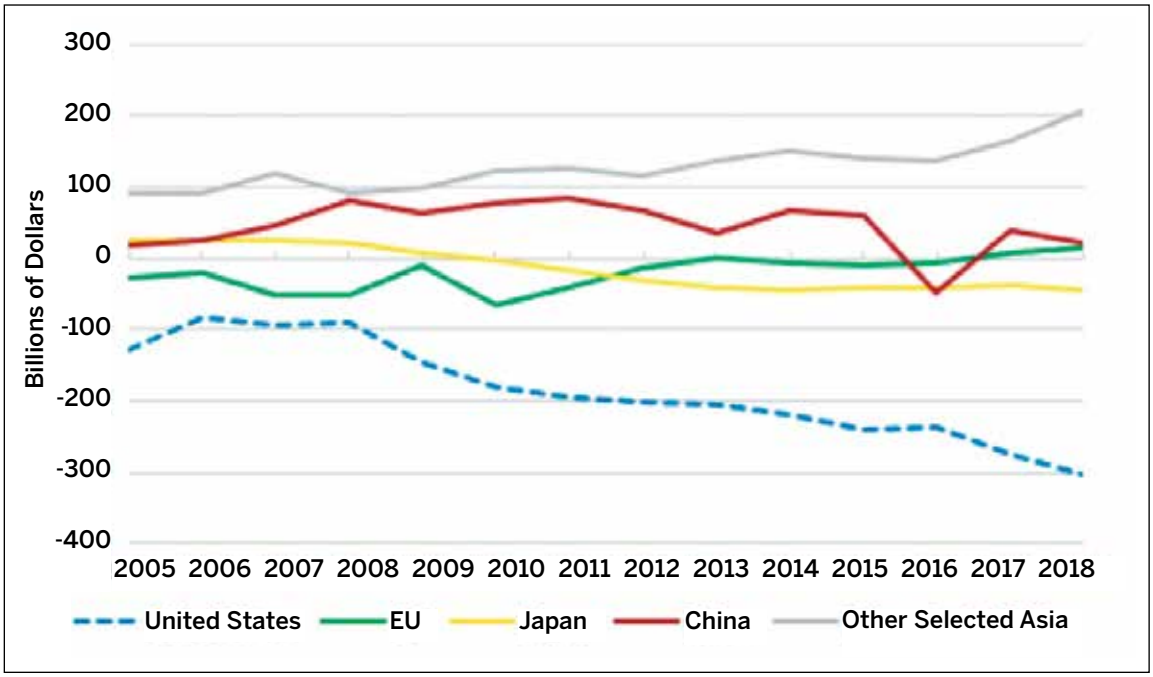
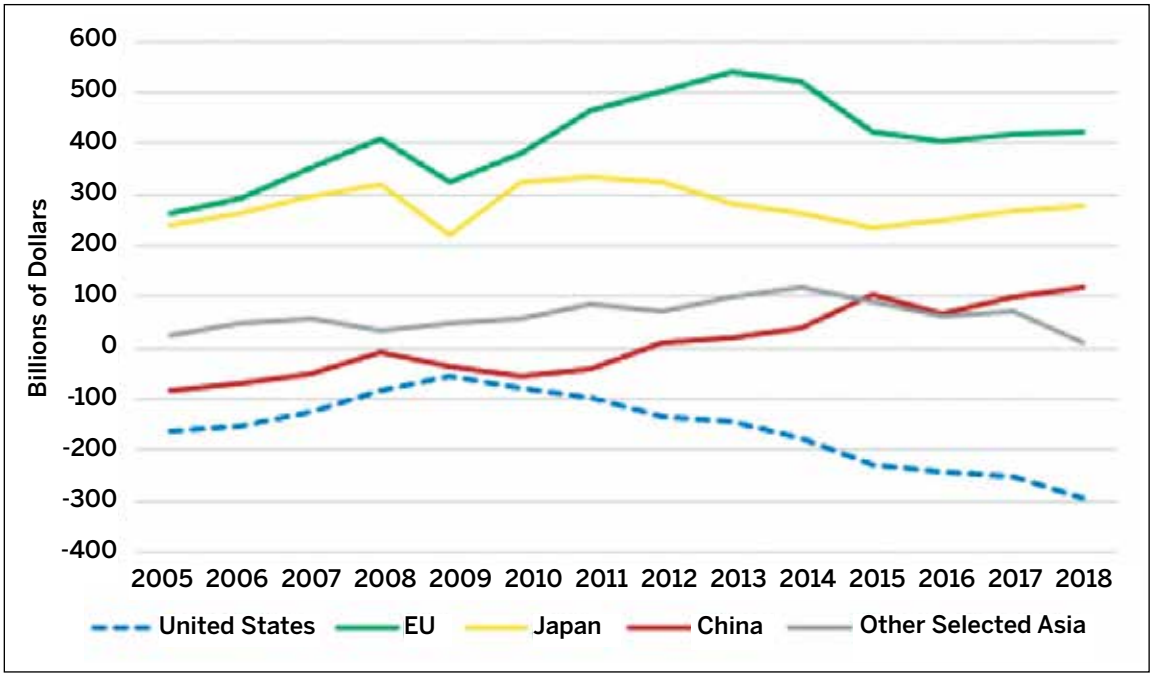


FIGURE 6. Trade Balance of Medium-high R&D Intensive Products



that can only be built and renewed through hands-on production. As noted, the result is now dependence on foreign suppliers and producers for not only critical commercial parts but also defense supplies and technology. As noted in a 2019 study by the Council on Foreign Relations, "Many advanced technologies necessary for national security are developed in the private sector by firms that design and build them via complex supply chains that span the globe; these technologies are then deployed in global markets. The capacities and vulnerabilities of the manufacturing base are far more complex than in previous eras, and the ability of the U.S. Department of Defense (DOD) to control manufacturing-base activity using traditional policy means has been greatly reduced."[39]

The most troubling implication is that the nation has little ability to manufacture the results of the $150 billion currently spent on R&D. The United States is already falling behind in international measures of economic complexity and innovation. For example, Harvard University's "Atlas of Economic Complexity" ranked the United States 12th in 2017, down from seventh in 2000, largely because the nation introduces too few products that contribute much to economic growth.[40] After receiving the highest ranking on the "Global Innovation Index" (GII) in 2008 and 2009, the United States has since placed as low as 11th. According to the 2019 "GII Report," other countries "simply achieve more with less . . . effectively translating their innovation inputs into a higher level of outputs."[41]

Entrepreneurial start-up firms should be a source of new products, but for a variety of reasons, start-up companies with new hardware inventions are rarely supported by the venture capital industry. When they are, investors typically pressure companies to manufacture in China. MIT's study, *Production in the Innovation Economy*, examined 150 hardware start-ups emerging from MIT research. The study found that these start-ups had access to sufficient skills and financing for R&D and initial product demonstration, but when the time came to scale production to commercial levels, the need for additional capital, production capabilities, and lead customers pushed most of these firms to move production abroad, usually to China.[42] Other studies have documented a slowdown in the formation of new manufacturing start-ups and continuing stagnation in their ability to scale production.[43]

Despite strong rhetoric and a multi-year trade war with China, the trend has not shifted. Production in China has proven to be too entrenched, too comprehensive, too compelling, and just too easy to drive a significant reshoring of manufacturing. At best, some American companies are reassessing their dependence on China in the wake of an uncertain trading regime and are diversifying production to locations such as Vietnam. But other countries—including the United States—do not have the capacity or suppliers to match the industrial ecosystem that China has built.

The coronavirus crisis has clearly revealed that broad-based, multi-industry dependence on foreign sources has reached a tipping point. China's plans for future technology development and dominance of global high-technology industries, as outlined in the 2015 industrial plan, *Made in China 2025*,[44] should be a Sputnik moment for the United States. Just as the Soviet launch of Sputnik in 1957 galvanized national resources to surpass the Soviet Union in launch capabilities, a similar national effort, encompassing both the public and private sectors, is needed to restore the U.S. industrial commons and build the manufacturing industries of the future in this country. The alternative is continued erosion of innovative capacity and production capabilities resulting in a second tier economy without the ability to support a first tier military.

POLICY RESPONSES TO DATE HAVE BEEN INADEQUATE

Solutions require concerted action by both the public and private sectors. The private company decisions that have resulted in the current weaknesses in U.S. manufacturing will not change without changes in the incentives that drive those decisions. These will require changes in government policy. The current administration and state governments have taken action to support manufacturing but, so far, they have been inadequate for the challenges. These initiatives include:

1. *Tax Reform*—The Tax Cuts and Jobs Act (TCJA) of 2017 had a number of provisions beneficial to domestic manufacturers. For example, it reduced the top U.S. corporate income

tax rate from 35 percent to a flat 21 percent, shifting from one of the highest rates in the world to one of the lowest. It increased depreciation to spur capital spending but eliminated the Domestic Production Activity Deduction, which was 9 percent. Other provisions encourage foreign profit repatriation, limit deduction of performance-based executive compensation, and discourage moving activities offshore.[45] Although it may be too soon to assess the impact of the TCJA on manufacturing location and investment decisions, initial indications are that public companies have spent tax savings on share buybacks rather than capital investments.[46]

2. *Manufacturing USA Institutes*—Beginning in 2012, the federal government, in partnership with state governments and private companies, has established 14 manufacturing institutes to develop new product and process technologies ranging from biofabrication to smart manufacturing.[47] Currently, three agencies—Defense, Energy, and Commerce—invest over $300 million in the institutes, matched by funds from states and industry.[48] Although generally successful so far, there are too few institutes to have a significant impact on the overall U.S. manufacturing sector, and the amount invested is much less than other advanced economies. It is also worth noting that China has imitated the program, creating its own National Innovation Institutes. China's program, started in 2015, has 8 institutes with a goal of 40 by 2025.
3. *State Initiatives*—Many state governments have programs to support manufacturing, most frequently to support workforce development but also research and technology development. The Oregon Manufacturing Innovation Center, the International Center for Automotive Research at Clemson University, and Virginia's Commonwealth Center for Advanced Manufacturing are examples of state-level initiatives that combine workforce training, research, and technology development working with industry consortia and higher education.[49]
4. *Congressional Initiatives*—Congressional leaders from both parties have drafted legislation to address weaknesses in U.S. manufacturing. Examples include the Industries of the Future Act of 2020, introduced by Sen. Wicker (R-MS), Sen. Peters (D-MI), and others; the National Institute of Manufacturing Act of 2019, announced by Sen. Peters at MForesight's National Manufacturing Summit in June 2019; and multiple provisions to encourage advanced manufacturing in the Small Business Administration Reauthorization Act of 2019.

These examples represent just a few of the manufacturing-related programs intended to help. The Government Accountability Office identified 58 such programs across 11different federal agencies.[50] All of them are relatively small and uncoordinated. They have not achieved the nationwide, systemic, strategic approach needed to restore U.S. manufacturing competitiveness, and arguably, hurt progress by giving the impression that the problems are being addressed already. The United States needs a comprehensive hardware innovation and manufacturing strategy that combines public and private initiatives with sufficient resources to shift the long-term trends in production, investment, and employment. Importantly, this strategy must be conceived and implemented with full recognition of the shifting technological and market changes that are affecting the global industrial landscape. The pandemic has shifted this landscape in ways that are still unpredictable. The crisis has not only raised questions about acceptable foreign dependencies on drugs, medical devices, and PPE, but also exposed weaknesses in domestic supply chains, logistics, and distribution. Addressing all of these will require a broad national conversation with a clear examination of lessons learned and reassessment of national priorities, while keeping in mind the long-term opportunities being created by new technologies.

A few examples illustrate the factors that should be considered in developing and implementing a long-term national manufacturing strategy:

1. *Electric Vehicles*—Although the market share captured by electric vehicles (EVs) is likely to increase gradually, the implications for the domestic automotive industry are profound. EVs require 40 percent fewer parts than existing vehicles, a number that will grow as new production technologies such as additive manufacturing reduce part counts further. Fewer parts, combined with other design innovations and continued advances in robotics and other automation, means easier assembly that requires less labor. Some of this drop in labor may be offset by other parts of the total EV ecosystem, such as battery production, charging infrastructure, and the sensors, electronics, and software used in EVs, especially as autonomous vehicles gain ground. These changes in the automotive sector, which has been one of the bright spots in U.S. manufacturing in recent decades, emphasize the need to control the total value chain in this country, which will require significant investment in skills, technology development, and production capacity.
2. *Industry 4.0*—The application of digital technologies to manufacturing is creating a sea change in the nature of production and, therefore, is creating an opportunity for U.S. manufacturing to regain competitiveness. Digitally connected factories and supply chains, relying on advanced sensors, data analysis, machine learning, and rapid connection potentially shifts sources of competitive advantage in ways that will benefit U.S. manufacturing. For instance, technology creates the ability to localize production of customized products in micro-factories, meeting consumer demand with less shipping and a smaller carbon footprint. The impact on manufacturing employment is difficult to project, but is more likely to be positive, across the whole ecosystem, especially compared to the devastating negative impact seen from offshoring. Again, the benefits will only be achieved if the necessary steps are taken to control the full value chain in this country. Competing nations, including Germany and China, are making significant investments to ensure their small and medium sized manufacturers are globally competitive by creating new programs to promote adoption of Industry 4.0 technologies ranging from loan guarantees for equipment upgrades to work-force development.
3. *Anchor Industries*—Emerging high-value, high-technology industries provide the greatest opportunity for the United States to take full advantage of the nation's R&D infrastructure and meet long-term national security needs. Examples include advanced semiconductors, advanced battery storage, synthetic biology, robotics, quantum information systems, and fifth- and sixth-generation telecommunications networks. Strong national support in these and similar industries to ensure that sufficient investment is made in R&D and the production capacity to manufacture the results will be essential to rebuild U.S. industrial competitiveness.
4. *Foundational Capabilities*—The United States needs to make concerted efforts to maintain or to rebuild its foundational manufacturing capabilities, including production technologies such as advanced machine tools, laser processing, 3D printing in multiple materials and in production volumes, methods to join dissimilar materials, and process capabilities to use advanced materials such as metamaterials and high-entropy alloys.

A NEW AGENCY TO REBUILD INNOVATIVE CAPACITY IN HARDWARE

The overarching lesson from these examples is that U.S. manufacturing policy must be future focused. The objective is not to restore lost industries but to rebuild lost capabilities. Although some foundational capabilities will need to be restored simply because so much knowledge and

skills have been lost through decades of offshoring, new skills, engineering capabilities, and production infrastructure will be needed. Currently, the country is not well prepared to do what is needed. The private sector will continue to respond to the same incentives and the same shareholder primacy paradigm. The DoD, though aware of serious shortcomings in defense supply chains, does not have the tools or the market presence to solve the problems by itself.[51] And simply throwing more money at existing programs or increasing federal R&D spending will not help if the country has lost the ability to generate national wealth from its R&D investments. Achieving change will require definitive action that makes clear the United States is serious about arresting the decline and restoring a strong manufacturing sector.

Currently, no federal agency has the health of the nation's manufacturing as its primary mission. DoD has the most critical interest and has a variety of relevant programs and initiatives, but simply focusing on critical defense manufacturing capabilities will not ensure a strong commercial production base and will not correct other critical national needs revealed by the national health crisis. Furthermore, justifying programs to support manufacturing solely on the basis of national defense disregards the crucial high-wage employment, innovation, and wealth building that only a strong, balanced commercial manufacturing sector can provide. This country needs a new agency with the mission to ensure that national health needs are met and that what is invented here is actually manufactured at scale here to give U.S. companies first mover advantages in the global market, which will strengthen military preparedness and create national wealth. Such a dedicated national agency—call it the National Manufacturing Foundation (NMF)—would have the resources and mission to mobilize the entire federal government, work closely with state governments, and engage the private sector.

Specifically, the NMF would implement the following six-point action plan:[52]

1. *Engage with other federal S&T agencies* to set technology priorities, mature promising product and process technologies funded through other federal agencies, access relevant expertise, and coordinate funding to ensure that promising technologies receive full support from discovery and invention to commercial-scale domestic production.
2. *Invest in translational R&D*—the applied engineering research necessary to advance technology and manufacturing readiness levels—to help advance emerging technologies beyond the pilot stage. This would include awarding grants and contracts to U.S. universities and other research institutions to support translational engineering (not science) research and manufacturing process technologies common to multiple industrial applications. This would also include establishment of a series of Translational Research Centers (TRCs) affiliated with universities. TRCs would focus on advancing technology and manufacturing readiness of emerging technologies in order to enable successful hardware start-ups and to transform research results into new products and processes manufactured in the United States.
3. *Build connections between hardware start-ups and other federal agencies,* especially the DOD, to support translational research in defense-critical technologies. This would include leveraging federal purchasing power and the federal government's role as a customer to help American companies procure financing for plants and equipment to establish and ramp up production of new technologies.
4. *Facilitate public-private partnerships to create Manufacturing Investment Funds (MIFs).* These MIFs would fill gaps in existing venture-capital markets, providing sufficient funding for hardware start-ups to scale production in the United States beyond pilot plants.
5. *Support small and medium-sized manufacturers (SMMs)* through technical assistance and financial support: including loans, grants, loan guarantees, and tax incentives. As the

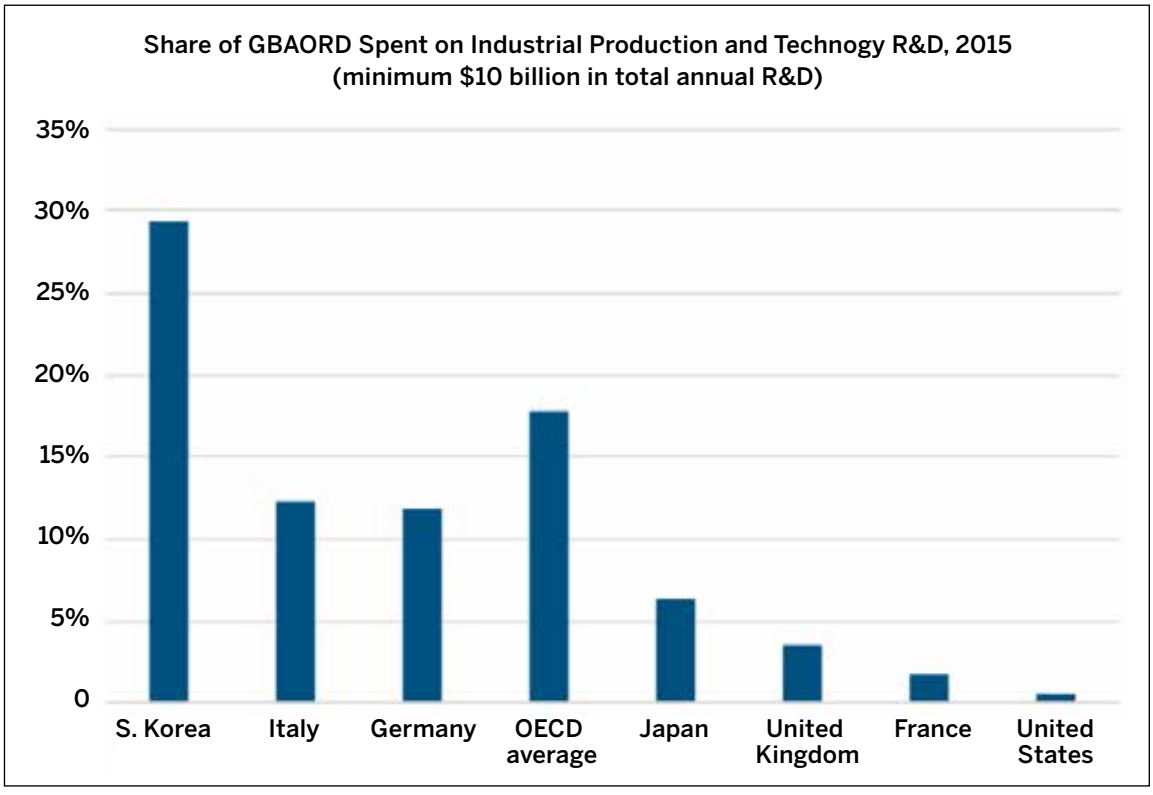
foundation of manufacturing value chains and the geographic distribution of diverse industrial clusters, it is essential that SMMs have the capacity to upgrade equipment, train staff, and fully participate in Industry 4.0.

6. *Grow engineering and technical talent at all levels* by significantly increasing federally funded graduate fellowships in engineering for qualified domestic students, partnering with state and local governments to increase the number of four-year engineering technology degree programs and to expand successful apprenticeship and skills-training programs.

This six-point action plan is designed to address multiple shortcomings in the current U.S. manufacturing innovation ecosystem. But to succeed, this plan must be complemented by policies ensuring that products based on the nation's R&D investments are manufactured domestically. In particular, a binding rule is needed that if the intellectual property for a product or process is developed based on federally funded R&D, then that product or process must be manufactured substantially (e.g., a 75 percent minimum value-add) in the United States, without any exceptions or waivers.

With its mission focused on holistic rebuilding of national manufacturing capabilities, the NMF should be funded commensurately. At least 5 percent of total federal R&D funding is appropriate—currently about $7.5 billion—although that amount would be less than competing nations, such as Germany, Japan, and South Korea, that spend 7-30 percent of government budget appropriations or outlays for R&D (GBAORD) on translational research (Figure 7).[53] In the context of the post-pandemic federal budget deficit, funding for a new federal agency, even such a modest amount, may be difficult politically. On the other hand, the costs to the nation of a weak and fragile manufacturing base have been made strikingly apparent, creating strong incentive to provide even more federal support for U.S. manufacturing.

FIGURE 7. Investment in Industrial Technology R&D as a Percentage of Total R&D



It is important for the NMF to have key objectives and metrics early in its existence. With the overall objective to strengthen foundational manufacturing and to advance domestic full-scale production of new hardware technologies emerging from federally funded R&D, metrics should be devised to determine progress toward meeting those objectives. Metrics to consider include the number of technologies successfully reaching commercial production, private sector job creation, new manufacturing facilities built in the United States, domestic availability of critical defense technologies, exports of advanced hardware technologies, and return on investment for both public and private stakeholders. Consistent tracking of metrics will allow for timely assessments and course corrections to ensure that the NMF remains focused on the success of the U.S. manufacturing sector and that NMF funds provide a return on investment to taxpayers.

The NMF would provide a focal point for the federal government's efforts to strengthen civilian manufacturing, a necessary condition for strong defense production. The DoD would work within the framework of the NMF to support translational research in technologies important to defense. The NMF would also facilitate connections between hardware start-ups and other federal agencies, especially the DoD, to leverage federal purchasing power as a lead customer. Government purchase orders can be used by new manufacturers to get financing for plant and equipment to scale production.

The NMF would intently focus on the success of domestic manufacturing. Procedures should be implemented to limit the possibility that the technologies, products, and processes supported by the NMF leak to foreign competitors. After all, the guiding mission of an NMF is to coordinate national resources to strengthen domestic manufacturing and to build the industries of the future in the United States.

Finally, if managed appropriately in collaboration and partnership with the private sector, NMF operations should accelerate technology commercialization without the specter of "picking winners and losers." Government has played an indispensable role in American industrial development throughout history. Government mandates in areas such as emissions control and vehicle safety, government mission priorities in space and defense, and long-term technical support in agriculture and electronics are all ways that the U.S. government has supported industrial development and global leadership. In fact, two leading U.S. manufactured exports are aircraft and weapons, areas with significant government R&D investment.[54]

The national emergency caused by the viral pandemic creates an opportunity to restore critical domestic production capacity and build the foundational capabilities and the skills needed to regain global leadership in advanced manufacturing. As creation of the Department of Homeland Security (DHS) following 9/11 demonstrated, a new federal agency can be created to meet urgent national need. Similar to DHS, the NMF would establish a national strategy, make necessary investments, take responsibility for manufacturing-related programs and initiatives across the entire federal government, including DoD, and be the focal point for a comprehensive national strategy and implementation to strengthen domestic manufacturing.

Importantly, the NMF would not simply be analogous to the National Science Foundation, whose primarily role is to provide research grants to academic researchers. The NMF—or National Institute for Manufacturing or, simply, Department of Manufacturing—would have a broad responsibility to coordinate federal and state initiatives, engage private industry and the education community, implement the six-point plan, and monitor results and adapt appropriately.

Creating a National Manufacturing Foundation is commensurate with the importance of manufacturing to long-term national wealth and security. By leveraging the discoveries and inventions emerging from existing R&D programs with a commitment to strategic, sustained investment in manufacturing, the NMF would help to establish the hardware industries of the future in the United States. The result will be a manufacturing sector that produces high-value defense, industrial, and consumer products with broad-based supply chains, diverse industrial clusters, and the foundational support for high-paying services that depend on strong manufacturing.

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ENDNOTES

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[6] U.S. International Trade Commission Sections 806.30 and 807 provisions permit the portion of the product made of U.S. components to enter the United States duty free.
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[8] Ibid.
[9] Ibid.
[10] https://fred.stlouisfed.org/series/RIWB00004S. Note that industrial production also includes mining and utilities.
[11] https://fred.stlouisfed.org/series/RIWG325S
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