POLICIES TO ENHANCE THE RESILIENCE OF US MANUFACTURING

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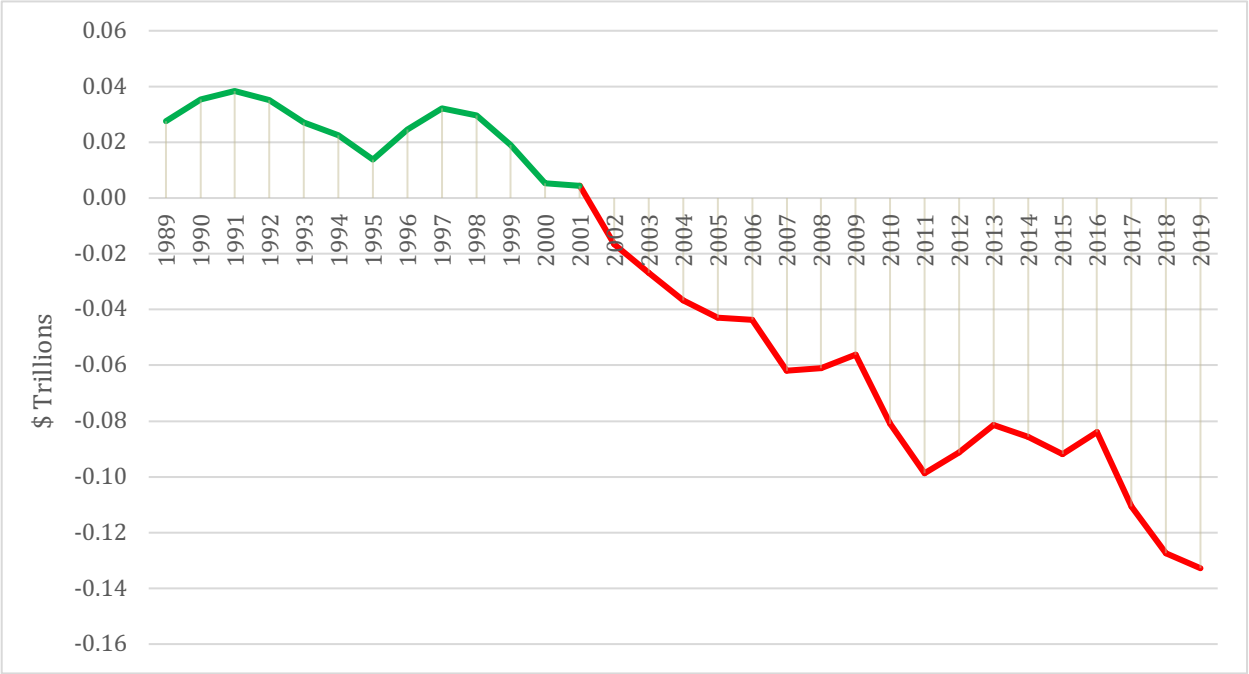
The COVID-19 pandemic has drawn worldwide attention to the fragility of global value chains for manufactured goods. In the United States, it is prompting a policy discussion about resilience—the ability to adjust in real time to supply chain disruptions while minimizing any loss to customers. Manufacturing firms are taking action, but what should the federal government do to enhance resilience? To address this important and timely question, we first define four components of resilience. We then consider more than 100 policy proposals offered over the past several years. Applying specific criteria, we make 15 specific policy recommendations, differentiating those that require congressional action from those that can be accomplished through presidential action. We conclude with some insights for policy makers, including the need for a top-down commitment, the development of a 21st century policy roadmap, and an emphasis on nurturing nascent capabilities in future technologies.

Long a driver of economic efficiency, globalization has lifted more than one billion people out of poverty (World Bank Group, 2018). It has also shifted production of goods in ways that have harmed US workers and local communities (e.g., see McLaren and Hakobyan 2016). The American mentality of "invent here, manufacture here" that dominated for decades after World War II increasingly gave way to "invent here, manufacture there" in the 21st century (Kota and Mahoney, 2019). And the decline in US global market share due to outsourcing and/or erosion of competitiveness hasn't been limited to labor-intensive goods providing little added value; the United States has a negative and growing trade balance in broad measures of advanced manufacturing, too (Kota and Mahoney, 2020) (See Figure 1).

But—to borrow a phrase from Bob Dylan—the times they are a changin'. After decades of trade liberalization, nations are raising tariffs. The WTO is no longer able to resolve trade disputes through its dispute resolution appellate panel because of concerns over its interpretation of WTO rules and its inability to sanction state subsidies and infractions of intellectual property rules. And "trade openness"—world exports as a share of world GDP—has been declining since the Great Recession. The world seems to be at an inflection point, where globalization gives way to a new era, one that emphasizes national security as much as maximizing shareholder value (Irwin, 2020).

It is against this backdrop that the world encountered the COVID-19 pandemic and responded with public health measures including social distancing and a deliberate pause in economic activity. These actions revealed the fragility of global value chains and US reliance on China, the so-called "factory of the world."

FIGURE 1. U.S. Trade Balance in Advanced Technology Products, 1989-2019.



Source: U.S. Census Bureau.

As a consequence of the pandemic, American manufacturers have consistently reported widespread supply chain disruptions (Keough, 2020). More than one-third of respondents to a March survey from the National Association of Manufacturers (2020) reported supply chain disruptions, and 50% did not have an emergency response plan in place. Three quarters of respondents to a June survey by the Institute for Supply Chain Management (2020) experienced disruptions, and 80% expect disruptions to continue in the third quarter. A July survey of US manufacturers (Gold, 2020) indicated continued widespread disruption that is fueling a shortening of supply chains to serve regional markets.

These pandemic-fueled disruptions are not only pressuring manufacturing firms, but also entire nations, to reevaluate supply chains:

- French President Emmanuel Macron—a previous champion of globalization—says the coronavirus exposed the "flaws and fragility" of France's overreliance on global value chains, and the need to "produce more, and not rely on others" (Rose and Kar-Gupta, 2020).
- Germany's health minister, Jens Spahn, wants to minimize "one-sided dependencies in order to win back national sovereignty" (Escritt, 2020).
- Japan has moved first; its national bank is allocating billions of dollars to assist its domestic manufacturers in re-shoring production from China (Reynolds and Urabe, 2020). Subsidies will cover relocation expenses and investments in automation (including robots).
- Other nations contemplating re-shoring include Australia (Tan, 2020) and South Korea (Yonhap, 2020).
- Many nations, especially in Europe and the United States, are also reviving ideas to create or protect "national champion" industries, not only in health care but in sectors important to national security and to competitiveness in advanced technologies of the future.

Similar ideas are percolating in the United States (Shalal et al., 2020) as it responds to COVID-19. Peter

Navarro, President Trump's manufacturing czar, argues that America needs to bring home its supply chains for essential materials. White House economic adviser Larry Kudlow has suggested tax breaks for re-shoring. In Congress, Senator Tom Cotton (R-Arkansas) introduced legislation to re-shore pharmaceutical supply chains[iv]; production of active drug ingredients is highly concentrated in India and China (Gibson and Singh, 2018). As this paper is being written, Congress is discussing a "Phase IV" stimulus package of between $1 and $3 trillion, in part to re-shore manufacturing supply chains and the inclusion of "Buy American, Hire American" provisions (Hoffman et al., 2020).

Should nations re-shore everything? No—there are reasons for international trade; comparative advantage is a powerful force that has greatly benefited consumers across the world. And although the pandemic has shifted the nature of comparative advantage and trade, a world without trade would be even more vulnerable to supply chain disruptions.[v]

How about re-shoring some things—those critical to national security or foundational to future economic growth? Probably a good idea—if we can correctly foresee which goods and supply chains will be critical in the future (not so easy), and if private sector firms are willing to relocate back to the United States (not a given).

A further complication: the next supply shock could occur anywhere and may or may not be a pandemic. For instance, the tsunamis in Japan and Southeast Asia severely disrupted manufacturing supply chains in recent years (Akkermans and Wassenhove, 2017). In 2010, the Chinese reduced supplies of critical raw materials to severely disrupt global production of high technology products (Tabeta and Zhou, 2019).

We expect US leaders will continue to develop and implement strategies closely tied to national security, including medical security. They will also develop and employ policy tools to combat the practices of competing nations (e.g., China) that undermine manufacturing competitiveness.

Our focus in this paper is on the concept of resilience—a manufacturing sector that can adjust in real time to supply chain disruptions while minimizing any loss to customers.

Importantly, we know how to increase resilience. First and foremost, management matters. A recent article in Harvard Business Review (Rice, 2020) lays out a three-step plan for manufacturing executives: map out your suppliers (including those far up the supply chain), conduct a vulnerability analysis, and develop contingency plans considering both the costs and benefits.

These actions apply to firms acting in their own self-interest. And, to be clear, US firms are considering—as a result of the pandemic—a range of actions to increase resilience—including, for example, increasing inventories, multi-shoring including regionalization, investing in automation, expanding the production flexibility of individual factories, and expanding use of contract manufacturing (Aylor et al., 2020; Shih, 2020; Smith, 2020).

Less clear is how the US government should act to advance the resiliency of its manufacturing sector to benefit the public. But in recent months, policy makers have taken notice. Congress held hearings on supply chain resiliency.[vi] The Trump Administration indicated its support for the re-shoring of semiconductors and essential medicines.[vii] And Presidential candidate Joe Biden offered his own multi-faceted proposal to enhance manufacturing resilience.[viii] This paper is intended to inform this ongoing policy debate.

COMPONENTS OF RESILIENCE

For the purpose of this paper, "US manufacturing" refers to manufacturing supply chains that serve US customers. We define "resilience" as the ability of supply chains to return to normal (or do even better) in serving US customers after an external disruption or economic shock. Resilience includes both resistance to a shock and recovery after a disruptive event. This definition is adapted from the academic literature in business management (Christopher and Peck, 2004, Christopher 2018). Importantly, we distinguish supply chain disruptions from a temporary surge in demand. For example, production of as-yet unproven vaccines—an extremely complex activity—is raising concerns about the capabilities of domestic manufacturers (Kaplan, 2020; Steenhuysen and Kelland, 2020) to meet what will be unprecedented global demand.

We assume that firms in the private sector will make adjustments to enhance resilience. Our aim is not to interfere with these adjustments. Instead, we focus on the role of government to provide capabilities that the private sector cannot be expected to develop on its own or might develop but at a slow pace. There is a public good, market failure, or government failure justification for the policies we identify.

We recognize that the benefits of a resilience-enhancing policy extend well beyond its narrowly defined cost. Nearly all of our policy recommendations provide benefits beyond resilience—for example, to enhance competitiveness (the productivity of firms in a specific geographic location) and/or sustainability (development that meets the needs of the present without compromising the needs of future generations).

We borrow, as a framework, four components of supply chain resilience, taken from the work of Christopher (Christopher and Peck, 2004, Christopher 2018). These four components represent "four legs" of the resilience "stool" we seek to build.

- *(Re-)engineering*. Supply chain risk—which can never be eliminated—is inherent in its design. Re-engineering supply chains can therefore lower risks. Re-engineering includes efforts at understanding vulnerabilities and challenges, developing a strategy, and designing supply chains to comport with the strategy. Importantly, there is often a tradeoff between efficiency and resilience. For example, increasing inventory will enhance resistance to a supply chain shock, but it comes at a cost and is contrary to the concept of "lean" manufacturing. For the purposes of government intervention, (re-)engineering would include efforts at re-shoring capabilities that had previously been outsourced, attracting new foreign direct investment to expand capabilities, and investing in R&D to support innovation. Such efforts could make supply chains shorter and simpler to serve regional markets, which not only enhances resiliency but also has the additional virtue of enhancing sustainability (Mandel, 2020).

- *Collaboration*. Collaboration involves all entities along a supply chain, and includes intelligence and planning. Shared information among supply chain partners is critical. Government can help by reducing the costs of supply chain collaboration across national borders (e.g., through trade agreements and regulatory cooperation), between levels of government (e.g., by aligning economic development initiatives), between government and industry (e.g., through information sharing), or between firms (e.g., via subsidies or tax breaks to encourage collaborative R&D).

- *Governance*. The risk management culture, which we will refer to as "governance," includes top-down oversight and rules to reduce supply chain risk. At the firm level, this would involve the

CEO and the Board of Directors and include clear lines of responsibility and relevant oversight mechanisms. At the government level, this includes actions to facilitate the risk management culture of firms (e.g., through provision of information) and to focus attention on issues of national importance. Governance would include monitoring of supply chain risk; development of strategic plans; and creating or amending legal authorities for intervention.

- *Agility*. Agility refers to visibility (see things sooner) and velocity (reduce the time to respond to an event). Christopher (2018) equates agility with the number of options available to a firm to respond to an event; agile supply chains are not "locked" into only one option. It would include flexible production technologies at the firm or factory level, and "smart manufacturing." Governmental efforts to enhance the agility of domestic manufacturers would include, for example, investments in infrastructure and incentives for workforce training.

Ensuring the resilience of US manufacturing requires attention to each leg of the stool. A governmental focus on just one component (e.g., governance) is not sufficient—resilience requires an array of actions.

APPROACH

To identify policy recommendations, we first gathered policy proposals that were raised in various events, reports, and publications of the Indiana University Manufacturing Policy Initiative (MPI) since 2015. These proposals were intended to address a concern about US competitiveness and fall into several policy categories: tax, international trade, workforce, technology, regulation, economic development, and governance. We added to this list additional proposals proposed or highlighted in 2020 as a response to the global pandemic and/or its economic impact. For example, Congress has held hearings on supply chain resilience featuring proposals from noted experts (e.g., Prasad, 2020), and some think tanks (e.g., American Compass, Hudson Institute) have brought together experts to opine on resilience strategies. The Progressive Policy Institute (2020) published a wide-ranging analysis of resilience proposals across different areas of the economy. From our aggregated list of 137 proposals, we looked for those that would, in our opinion, best enhance the resilience of US manufacturing.

Greater resilience, however, comes at a price. And in the current pandemic-fueled recession, manufacturers are not likely to invest for long-term resilience when facing short-term existential threats like meeting payroll or paying vendors.[ix] Therefore, we excluded from consideration proposals, such as government mandates, that would impose significant near-term costs upon US manufacturers during the ongoing economic downturn (such as a mandate for each firm to develop an emergency plan to respond to a future supply chain shock). We also excluded from consideration proposals expected to garner relatively narrow political support (such as shifting health care costs from employers to taxpayers).

For the selected proposals, we determined whether adoption requires action by the executive branch or legislative branch. Because executive branch action ensures more rapid implementation, we note these proposals accordingly.

LIST OF POLICY RECOMMENDATIONS

We make the following recommendations under each leg of the resilience stool.

1. *(Re-)engineering*
    - Employ certain criteria for economic development projects.
    - Develop access to critical minerals.
    - Increase funding and enhance incentives for industrial R&D.
    - Develop a "stress test" for supply chains.

2. *Collaboration*
    - Enhance US participation in development of international standards for smart manufacturing and advanced technology industries.
    - Invest in pre-competitive, collaborative research in nascent technologies.
    - Together with allied nations, subsidize domestic production of goods critical to national security.
3. *Governance*
    - Amend federal authorities to better respond to a future supply shock.
    - Designate a White House-level manufacturing czar and develop a national strategic plan to ensure long-term manufacturing competitiveness.
    - Identify critical supply chains at highest risk.
    - Reform the WTO.
4. *Agility*
    - Create incentives for employer-driven workforce training.
    - Invest in infrastructure.
    - Replace the R&D tax credit with an innovation and competitiveness credit.
    - Share best practices with SMEs.

We now describe each specific policy recommendation.

(RE-)ENGINEERING

1. *Employ certain criteria for economic development projects.*

In recent decades, the US manufacturing sector has outsourced jobs to countries with lower labor costs. As Kota and Mahoney (2020) pointed out, the United States evolved from a mindset of "invent here, manufacture here" to "invent here, manufacture there," driven by the profit motive of multinational corporations. The "smiling curve," popularized by business schools, reflects this mindset, where manufacturing operations are seen as providing less value-add to a firm than upstream (R&D) or downstream (marketing) activities. Offshoring became more pronounced with the rise of China as a manufacturing powerhouse, which can be traced to its 2001 entrance into the World Trade Organization (Brent, 2019; Hammer, 2017). One consequence: a steep drop in US manufacturing employment between 2000 and 2010, attributed in part to international trade and trade policy (Pierce and Schott, 2016).[x]

With the outsourcing of US jobs comes an outsourcing of US capabilities, resulting in what some academics (Shih, 2009) call the "hollowing out" of US manufacturing. Those favoring a re-shoring of these capabilities (e.g., Moser, 2020) argue for changes to policy, including changes to government procurement

and tax reform. Meyer (2020) argues for changes in international trade policy because current trade rules discourage domestic regulation of supply chains.

We are wary of re-shoring as the primary strategy to ensure resilience for three reasons. First, the term is unnecessarily narrow. New capabilities arise not only from re-shoring, but also from foreign direct investment and nascent industries. All should be encouraged. Second, the forces that resulted in offshoring may not easily be overcome; attention must be paid to opportunity cost. For example, a firm may choose to relocate capabilities from China to a nation with lower labor costs than the United States (e.g., Mexico) or to another Asian nation with a near-identical value chain (e.g., Taiwan). Finally, we must be aware of possible retaliatory actions by other large players such as Europe and China if we move too aggressively on reshoring. Nevertheless, re-shoring may be the only mid-term viable option once national priorities are set.

To assuage our concerns, we recommend that policy makers focus foremost on growing US capabilities, which indirectly will bring back offshored jobs. Capabilities—not simply jobs—define resilience. And policy makers should employ three criteria when prioritizing potential economic development projects, including re-shoring projects:

- First, the most worthwhile projects should provide a capability that is additional to those already possessed by the United States. The capability could be in the form of a product or a process. Projects that simply shift the location of a factory from one US state to another do not represent an additional capability.
- Second, a project should offer a capability critical to US economic or national security. A critical capability may be one with broad (semiconductor production) or specific (permanent magnets in missile systems) application.
- Third, a project should be economically viable. A project not expected to survive without significant government subsidies in perpetuity will require greater justification than a project expected to stand on its own within five years. Seen in this way, projects should be prioritized based on the ability of a particular location to support it.

Each criterion is necessary to ensure governmental resources are both effective and cost effective.

2. *Develop access to critical minerals*

Mineral resources are a good starting point for identifying critical manufacturing capabilities. Mineral resources undergird the competitiveness of the manufacturing sector—a fact not lost on other nations. In particular, China is exploiting its own natural resources and gaining control of resources in other countries, to support advanced industries. China's tactics, encapsulated in its Made in China 2025 and Belt and Road (BRI) programs, include purchasing mining assets from Central Asia to Africa, South America, and Australia (Lee, 2015). China has emphasized natural resources in its strategic investments. In the first decade of aggressive Chinese state investment to acquire natural resources outside its own borders (2005-2018-5) nearly 50% of its purchases were in energy and 20% in mineral resources (Lee, 2020).

For example, China, through the use of subsidies and lack of high environmental standards, holds a near monopoly in the mining of rare earth minerals, critical to nearly all advanced technologies (Carrell and Belton, 2019). According to the U.S. Geological Survey, China is responsible for 71% of global production.

The United States produces virtually no rare earths as of mid-2020. Between 2014 and 2017, 80% of U.S. imports came from China, while the remaining 20% was originally processed in China. For particular steps in the processing of rare earth minerals—for example, the metallurgical transformation of rare earth oxides into finished parts—China has a near-complete monopoly. Because of its market power and its past willingness to leverage this "soft" power[xi], China poses a potential threat to U.S. national defense. Rare earths and related metals such as gallium and tellurium are also crucial components of high-tech industries such as semiconductors, solar cells, and fiber optic systems. China also controls a large majority of the metals used in lithium ion batteries, important to electric vehicles, cell phones, and solar electric power plants.

As a first step to counter efforts by our strategic competitors, Congress should enact the American Mining and Security Act, sponsored by Senators Lisa Murkowski (R-AK) and Joe Manchin (D-WV).[xii] The bill would require the identification and designation of critical minerals, followed by an assessment of current and future US supply and production, establishment of a federal research program to improve production, processing, and recycling; development of capabilities in forecasting; assessment of workforce needs and development of workforce training programs. This bill is especially important because it focuses on minerals used in commercial applications not covered by DoD priorities. However, passage of such a law would be insufficient to counter China's policies. Federal subsidies for production capacity may be needed to create a level playing field.

Some critical minerals may not be found in the United States in sufficient quantities. Therefore, to ensure reliable supplies, the United States ought to coordinate with other nations, including the "Five Eyes" group, which includes the United States, Canada, Australia, the United Kingdom, and New Zealand (Rogers et al., 2020). Historically consistent allies, these nations share a common economic philosophy as well as a willingness to push back on growing Chinese influence. They can be trusted to be part of critical supply chains. Fortunately, members of this group are significant producers of minerals and metals—and manufactured goods—needed for defense and advanced technology leadership.

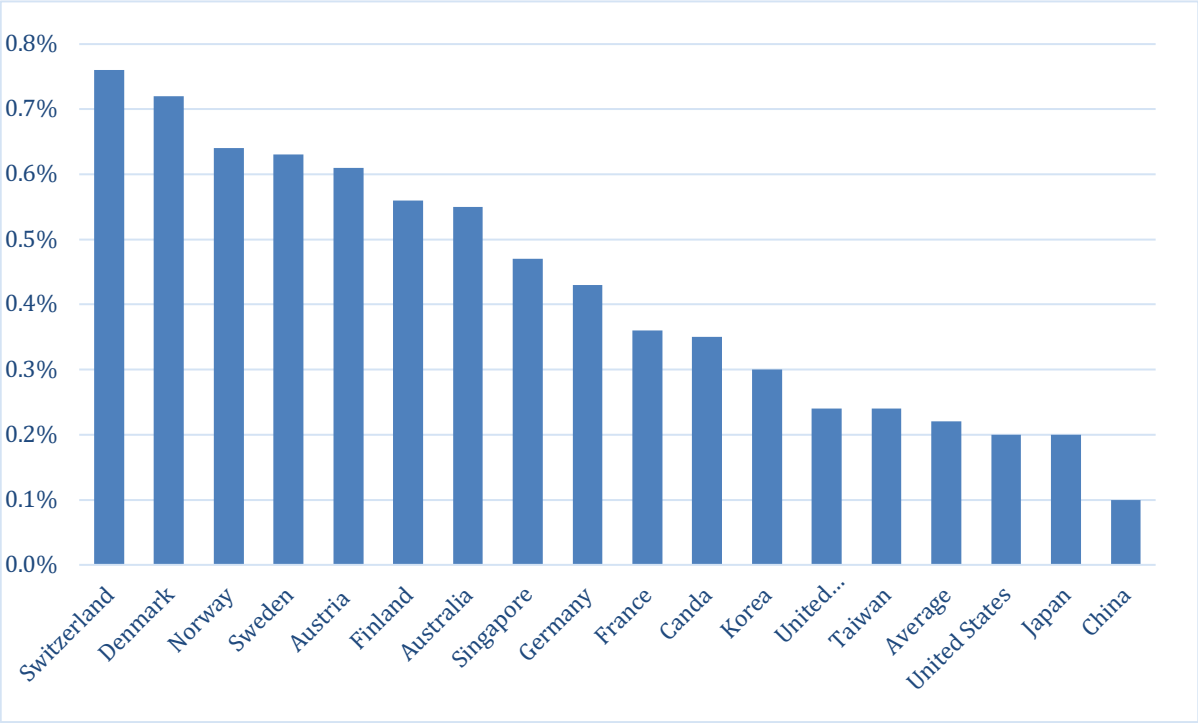
3. Increase funding and enhance incentives for industrial R&D

The resilience of manufacturing depends on expanding capabilities, which is inextricably linked to R&D investment. This is the US experience—in the decades following WWII, significant and consistent R&D spending bolstered US manufacturing capabilities in such fields as biomanufacturing, materials science, aerospace, and information technology.

Today, the United States leads in several key R&D indicators: government R&D spending, total R&D spending (government and business), new science and engineering journal articles, and new science and engineering doctorates (Khan et al., 2020).

However, these statistics are not on a per capita basis, and the rest of the world is catching up. China is on track to surpass the United States in R&D spending, and 27 OECD nations exceed the United States in university R&D investment as a share of GDP (Atkinson and Foote, 2019) (Figure 2). These dynamics reflect flat US government investment in nondefense R&D in the 21st century as a share of GDP (Atkinson, 2020; Shih, 2020).

FIGURE 2. Government funding for university R&D as a share of GDP, 2017.



Source: Atkinson and Foote (2019); adopted from OECD data.

Following the lead of many others (e.g., Atkinson, 2020; Shih, 2020), we recommend that the United States increase government investment in R&D. According to Shih (2020), the form of this investment could be in platforms or mission-critical programs (e.g., the Human Genome Project), and could be linked to collaborative efforts with industry and academia. According to Atkinson (2020), the US government should spend at least $100 billion per year through a more generous R&D tax credit, funding of industrially relevant R&D, and demand-led investments (e.g., in a modernized electric grid.)

4. *Develop a "stress test" for supply chains.*

After the last financial crisis, the idea of a "stress test" for financial institutions, which became law, garnered acceptance. According to Simchi-Levi and Simchi-Levi (2020), governments should consider applying a "stress test" to the supply chains of companies that provide critical goods and services. This stress test would assess how fast supply could recover from disruptive events.

This stress test would be developed under the auspices of the federal government "manufacturing czar," described below. It would have to account for a variety of different shocks, from pandemics to natural disasters to climate change to major conflict. One important decision to be made is whether the stress test would be "self-graded," or assessed by a government agency. Perhaps the most practical solution would be to have the National Institute of Standards and Technology (NIST) develop a voluntary stress test to be used at the discretion of private industry. It could also serve as a gold standard for manufacturing firms serving national security—including medical security--needs. Importantly, the stress test should also be employed by the US government for the nation as a whole, to identify significant weaknesses and to set national priorities.

COLLABORATION

1. *Enhance US participation in development of international standards for smart manufacturing.*

Technical standards are specifications, in the form of rules or guidelines, for materials, products, processes, or services (such as communication between machines, systems, hardware, and software). Standards often are based on technologies that embody intellectual property (IP). Without technical standards to govern the flow of information within and across a firm and its supply chain, smart manufacturing (which advances resiliency) cannot happen. Development of standards often arises through the efforts of International Standards Organizations (ISOs).

Leading manufacturing nations often take a strategic approach to technical standards. China's government participates actively in global standard-setting bodies that are of strategic importance. It is aggressively writing standards for emerging technologies such as 5G telecommunications to benefit its own firms, and frequently attempts to influence ISOs by group voting of its company representatives and flooding the technical committees with low quality patents. And it is "exporting" its own standards though its "Belt and Road" initiative. Germany, which first foresaw the importance of smart manufacturing, has shepherded the development of rigorous and comprehensive technical standards in the so-called Industry 4.0 technologies (Ezell, 2018).

In contrast, the United States encourages a voluntary, consensus-based approach where government agencies participate only when invited by industry. The lack of a single driving national strategy does not provide the same level of certainty for investment as compared with the standard-setting approach of China or Germany. Notably, small and medium enterprises, including technology startups, seldom participate in standards development (Manufacturing Policy Initiative, 2019) due to the cost of obtaining voting rights in ISOs and the cost of travel and participation in ISO meetings.[xiii]

The United States, through NIST, should monitor the efforts of Chinese firms (often assisted by participating members of the Chinese Communist Party at ISO meetings) to undermine the expert consensus model that has prevailed in these institutions. It should work with allies in Europe, Japan, Korea and others to preserve the integrity of the consensus process at ISOs. The United States should also encourage SME participation in the development of technical standards of strategic importance to smart manufacturing and its associated technologies. Specifically, the Internal Revenue Service should clarify that the cost of participation in standardization bodies is eligible as a qualifying expenditure under the R&D tax credit and should develop guidelines on this matter. And Congress should direct NIST to reduce the cost of obtaining voting memberships in key ISOs and provide $5 - $10 million in funding for NIST-administered grants to acquire voting memberships.

2. *Invest in pre-competitive collaborative research.*

The nature of innovation has evolved over several decades; breakthrough innovations at the frontiers of technology are increasingly associated with multi-disciplinary teams of researchers. And the resources needed to overcome the technological "valley of death" – the gap between basic R&D and commercialization—often discourage even the most well funded firms. According to Mazzucato (2014), public funding is often necessary to "de-risk" private sector investment, as has been the US experience in smartphone technology and breakthrough drugs. In past decades collaborative research has been successful for the satellite (Comsat) and semiconductor industries (Sematech).

For these reasons, investment in pre-competitive collaborative research makes sense. Partners share resources on a technology platform that offers the opportunity for independently developed differentiated products in the future. Efficiency drives this model of research. Such collaboration can be just between private sector firms or across industry, government, and academia.

Shih (2020) identifies potential projects suitable to pre-competitive consortia, including biomanufacturing. A current example is the Manufacturing USA program, designed to speed the commercialization of advanced manufacturing technologies.

Other nations see value in pre-competitive collaborative research. Germany's famed Fraunhofer Institutes utilize this model. As part of its Made in China 2025 program, China is developing 40 "manufacturing innovation centers" and is investing significantly more resources than the United States.

There are 15 Manufacturing USA institutes, each focused on a particular platform technology (e.g., industrial robotics, lightweighting, bioprocessing). ITIF (Ezell, 2016) has recommended expanding the number of Manufacturing USA institutes from 15 to 45. More emphasis should be placed on technologies offering greater manufacturing flexibility such as additive manufacturing, collaborative robotics, and digital connectivity within a factory or across supply chains. This approach could also be used for process technology for converting raw materials such as rare earths to usable metals, or for advanced biotechnology production.

3. *Together with allied nations, subsidize domestic production of goods critical to national security.*

As previously described, economic development projects should be prioritized based on promised capabilities: additional, critical, and viable. Moreover, allied nations could jointly contribute to the cost of developing a new production capability that would otherwise be too risky. An obvious contemporary example is developing a vaccine for the COVID-19 crisis. Another might be processing rare earth oxides into metal parts for technological applications—pervasive in dual use (military and civilian) technologies—an idea that the Department of Defense is exploring with Australia. Investment in such capabilities could be shared across allied nations to ensure long-term economic viability. A third example is production of the F-35 fighter jet, in which ten allied nations contributed to development costs.

GOVERNANCE

1. *Amend federal authorities to better respond to a future supply shock.*

Congress should provide oversight and amend, as needed, existing authorities to reflect lessons learned from the ongoing pandemic that would enhance resilience to a future supply chain shock. For example, the following bills have been introduced in Congress to reform the National Stockpile Act and deserve consideration:

- H.R. 6516, the Stockpiling for America's Future Endeavors (SAFE) Act, sponsored by Reps. Brooks (R-IN) and Schrier (D-WA), would allow the Strategic National Stockpile to accept gifts from individuals and firms. Currently, such gifts require approval by HHS and GSA through a process that has been described as cumbersome.

- H.R. 6517, Stockpile Inventory Modernization Act of 2020, sponsored by Reps. Brooks (R-IN) and Eshoo (D-CA), would allow the SNS to sell items no longer needed. During the ongoing pandemic, SNS distributed items that had passed the expiration date.

- H.R.6531, Medical Supplies for Pandemics Act, sponsored by Reps. Dingell (D-MI) and Walorski (R-IN), which would create incentives to diversify production and increase emergency stock and work with distributors to manage stock.

Similarly, Congress should consider reforms to the Defense Production Act, including an update the Act to reflect the digital transformation of the economy not envisioned by the authors of the 1950s era statute (Long, 2020). This would entail updating the Act to allow data access by the federal government in emergency situations and investment in infrastructure and human capital to leverage the data and make real-time decisions. The Act should also require efforts to ensure equitable distribution of goods produced under the Act.

Oversight hearings have also identified important regulatory reforms that have or could enhance resiliency. For example, witnesses at a June 2020 hearing on supply chain resilience held by the House Committee on Small Business commended the Food and Drug Administration (FDA) for creating a blanket emergency authorization for face shields that meet a set of simple criteria, reducing delays in meeting the upsurge in demand (Billstrom, 2020). However, that same witness called out FDA for not providing emergency authorization for fabric face masks meeting certain criteria; FDA approval is needed for medical institutions to purchase them (Billstrom, 2020). We recommend that regulatory agencies identify and implement reforms to existing regulations that have proven to be barriers to resiliency during the COVID-19 pandemic.

2. *Designate a manufacturing czar and develop a national strategic plan.*

To ensure resilience, governance measures should include a commitment by the President and a strategic plan to align activities toward national goals. The Chief Manufacturing Officer Act, sponsored by Rep. Tim Ryan (D-OH), would do just this, placing a Senate-confirmed CMO in the White House and tasking the CMO with developing a national manufacturing strategy.[xiv] The CMO would also coordinate among the disparate federal programs aimed at domestic manufacturing. According to Government Accountability Office (2017), 11 federal agencies operate 58 programs to benefit US manufacturing in whole or in part; these programs spent approximately $7 billion in fiscal year 2015. (See Table 1.) This GAO report underscores a lack of top-down coordination across these programs.

We recommend that the strategy include ensuring the resilience of supply chains, and that this task be listed explicitly in the legislation. We also recommend that the strategy include actions to ensure US leadership in smart manufacturing. In particular, the plan should include governmental actions to ensure a foundation of information governance (Belton et al. 2019) to support smart manufacturing.

TABLE 1. US Federal Spending on Manufacturing Programs.

Agency	Number of Programs	Program Obligations ($millions)
Small Business Administration	4	2,549
Department of Education	2	1,123
Department of Agriculture	2	1,059
Department of Labor	4	791
Department of Energy	9	452
Department of Defense	9	411
Department of Commerce	13	377
Department of HHS	3	330
National Science Foundation	10	180
Export-Import Bank	1	107
Environmental Protection Agency	1	4

Source: US GAO (2017).

3. *Identify supply chains at highest risk.*

Absent an objective analysis of US supply chains, governmental decisions to support re-engineering supply chains will favor advocacy organizations yielding the most political clout. To ensure that policy makers are focused on critical capabilities, a federal agency with expertise in manufacturing should be tasked with identifying those supply chains at highest risk of disruption.

The US GAO "high-risk" series provides a model for doing this. In 1990, GAO began an effort to identify federal programs at high risk for waste, fraud, and abuse, and mismanagement. GAO created a "high risk" list of federal programs aimed at drawing attention to specific problems and facilitating reform. GAO reviewed and updated the list periodically. The latest report was issued in 2019 (US Government Accountability Office, 2019). The Department of the Interior has also issued a comprehensive report on critical minerals, including those important to manufacturing.

We recommend a similar effort focused on critical US supply chains of greatest risk for disruption. The Department of Commerce International Trade Administration should be designated to undertake this effort, which would involve an initial report and annual update, which could include additions or removal of specific supply chains depending on the latest data. The role of ITA should be analysis; policy recommendations should be left to Congress or the President. ITA should, however, develop objective and transparent criteria for list inclusion or exclusion.

An open question is whether ITA would have access to data relevant for supply chain analysis. Such data could be acquired via the Annual Survey of Manufactures. ITA should be tasked with looking into this matter and working with the Census Bureau to ensure it collects the needed data.

4. *Reform the WTO.*

International trade growth fostered an unprecedented rise in global prosperity in the post-1945 period. But in recent years it has encouraged the prolonged atrophy of American industrial capacity and an erosion of domestic supply chains.
Trade policy reform in general, and WTO reform in particular, is essential to addressing these trends.

What is needed is a different set of fundamental principles: reciprocity, national security, and democratic oversight.

Reciprocity implies equal access to market opportunities. Reciprocity is undermined when China systematically subsidizes exporters and appropriates intellectual property while restricting access to its markets, or Europe applies higher tariffs on autos and blocks imports of genetically modified products while offering no offsetting measures, or India refuses to honor pharmaceutical patents.

National security imperatives are crucial to any trade and related investment policy. U.S. Trade Representative Robert Lighthizer (2019) is right to insist that each nation has an absolute right to determine its own security imperatives and meet them with domestic resources.

Democratic oversight of trade policy by sovereign states must also be restored. The United States, as well as other WTO members, should not be forced to accept WTO over-riding decisions based on its own analysis of national security needs, or over-riding important domestic laws. Nor can members accede to creation of new WTO rules without group deliberation of those rules.

In practical terms, this means that Congress can decide whether the resilience of medical or certain high-technology supply chains should override WTO rules or the narrow economic considerations of lower-cost production.

Adherence to these fundamental principles requires reform of the WTO. The WTO was always conceived as supranational in character, with rules that take precedence over domestic law. And over time, the WTO has proved incapable of enforcing existing rules and addressing 21st century problems such as forced technology transfer and state subsidization of industry (Duesterberg, 2019).

Currently, any change to WTO rules requires unanimity of its more than 160 members, which effectively blocks any attempt to create new rules for the modern economy. The United States should address these problems by working with allies to reform the WTO. Most importantly, the organization's unanimity rule should give way to alternative decision-making reflective of member-party priorities (Duesterberg, 2020).

There already exists a model for this. WTO-compliant rules for plurilateral agreements allow a supermajority of members to approve agreements that cover 75%-90% of trade in a given sector, such as the Information Technology (products) Agreement of 1997. WTO rules also allow for services agreements subject to the three-fourths supermajority rule for consensus.

A WTO reform agenda should also include establishing better rules to limit the role of state subsidies and the power of state-owned enterprises. Subsidies underpin the Chinese march to technical parity and trade advantage encapsulated in its Made in China 2025 program (Lee, 2020).

Absent a WTO-brokered solution, the United States should pursue other policies to combat China's strategy—either with a coalition of the willing or, if necessary, by leading on its own. Coordination with longstanding allies in the "Five Eyes" group would be a good place to start (Rogers et al., 2020). And the United States should re-join the Trans-Pacific Partnership, now known as the Comprehensive and Progressive Trans-Pacific Partnership (CPTPP).

AGILITY

Agility includes flexible manufacturing systems, such as the reconfiguration of a factory to change its product mix and/or to change capacity quickly and efficiently. Examples include an auto assembly line that can produce multiple vehicle models, steam cracking of hydrocarbons into ethylene that can utilize either oil (naphtha) or natural gas (ethane) as a feedstock material, or a furniture maker that can produce dozens of different chairs or tables from the same machine. The main advantage of a flexible manufacturing system to a firm is long-term efficiency, and the disadvantage is typically higher cost for installation and worker training.

Agility also includes smart manufacturing—the digitalization of manufacturing at the production unit, factory, or supply chain level. Seen as the next industrial revolution (also called Industry 4.0), smart manufacturing utilizes a variety of technologies (e.g., artificial intelligence and machine learning, collaborative robots, 3D printing, and cloud computing) but the common factor is the acquisition, analysis, and management of data. A smart supply chain is inherently more resilient because it can react more quickly to disruptions anywhere in the world. Like flexible manufacturing, smart manufacturing promises long-term efficiency but at a higher up-front cost. And both flexible manufacturing and smart manufacturing require skilled labor for maintenance and operation.

1. *Increase incentives for employer-driven workforce training*.

An agile supply chain requires skilled workers. We agree with Cass (2020), who argued that government ought to do more to encourage employer-driven workforce training. The following policies that would do just this:

- Increase funding for the Perkins vocational education and training programs.
- Raise the limit for the employer higher education credit (i.e., the Section 127 program).
- Follow the lead of South Carolina by offering a tax credit for each new apprentice at manufacturing establishments. Consider a similar tax credit at the federal level.
- Follow the lead of the Trump Administration and encourage the development of third-party credentialing for workforce skills at the individual level and the portability of such credentials.
- DOL ought to conduct research to identify particular skills expected to be in high demand for manufacturers in the future and periodically update this list of skills.

Immigration provides a critical influx of skilled labor when the domestic labor supply is insufficient or unlikely to provide sufficient capabilities. For this reason, we oppose actions by the federal government to restrict visa programs designed to ramp up skilled labor to meet the needs of manufactures. Even a pause in such visas—as is currently the case for the H-1B (skilled workers) visa and the L-1 (company transfer of foreign executives) visa—creates business uncertainty and increases the likelihood of permanent offshoring (Tobocman, S. 2020).

2. *Invest in infrastructure.*

Manufacturers rely on US infrastructure (highways, bridges, airports, dams, levees, ports, rail, wastewater, etc.), which is in dire need of repair and modernization.

The US currently spends an estimated 2%-3% of GDP on infrastructure—much less than it did in previous decades and far lower than that of other nations (Keeley, 2020).

According to the 2017 US Infrastructure Report Card, the United States received a "D+" grade. Bringing this grade up to a "B" would require $2 trillion investment through 2025, according to the American Society of Civil Engineers (2017). Table 2 shows needed funding by infrastructure type. As Congress mulls an infrastructure package, perhaps as part of its Phase IV stimulus package, a price tag of between $2-4 trillion seems politically feasible.

TABLE 2. Cumulative Infrastructure Needs in 2020 (in $2010 billions).

System	Total Needs	Expected Funding	Funding Gap
Surface Transportation	1,723	877	846
Water/Wastewater	126	42	84
Electricity	736	629	107
Airports	134	95	39
Inland Waterways and Marinas	30	14	16
TOTALS	2,749	1,657	1,092

Source: American Society of Civil Engineers (2017).

Such investment would improve the resilience of US manufacturing supply chains by ensuring reliable delivery times and minimizing fleet maintenance costs. It would also create jobs in the short run by stimulating demand for manufactured material inputs (McGarry, 2020).

For many years, the key roadblock to a major infrastructure bill is who would pay for it. The COVID-19 pandemic has greatly reduced air and highway travel, resulting in a drop of revenue from user fees and gasoline taxes—revenue that would otherwise be used to fund infrastructure improvements. Now, more than ever, the federal government must step up with the needed funding.

We see the return on investment in infrastructure important to manufactured goods as greatly exceeding the cost and therefore we are less concerned about the most equitable cost sharing mechanism. The sooner that such infrastructure (freight systems, ports, rail linkages, freight highway corridors) can be maintained and improved, the less the final price tag will be.

As we write this paper, there is talk in Congress of using an infrastructure bill to pay for re-shoring of specific supply chains, such as medical supplies, pharmaceuticals, and semiconductors. We see this as logical; quality infrastructure in itself is a major draw influencing the location decisions of global

manufacturers (Deloitte, 2015; McKinsey, 2017; PwC; 2019) and attracting imports (by lowering the cost of transportation).

3. *Replace the R&D tax credit into an innovation and competitiveness credit.*

Atkinson (2020) argues for an American Innovation and Competitiveness Tax Credit, which would be an expansion of the current R&D tax credit to cover not only R&D expenditures, but also equipment purchases and workforce training—activities that directly promote innovation and productivity growth and for which firms would otherwise underinvest because they do not recover the full value because of positive externalities. He suggests it be set at a level that is less than the high hurdle rate that major firms typically use when considering capital expenditures. We concur with this proposal, which would cover a range of activities associated with innovation and would encourage additional innovation rather than replace investment that would otherwise occur.

4. *Share best practices with SMEs.*

The Manufacturing Extension Partnership (MEP) is a federal program that works through individual states with small and medium manufacturers to boost productivity. Just as the Agricultural Extension Service provides critical information to local farmers, the MEP provides critical information to local manufacturing firms. Importantly, MEP addresses a contemporary problem—lagging productivity growth, especially among smaller firms. Academic evaluations of the MEP show a significant return on investment.

We recommend that funding for the MEP program be at least doubled (as suggested by Ezell (2020) and perhaps quadrupled (as suggested in the Biden manufacturing plan[xv]), and that the required state/federal cost share be relaxed from 2:1 to 1:1, as suggested by Ezell (2020). In addition, MEP ought to articulate the value of smart manufacturing platforms to its clients and encourage participation (Mandel, 2019).

CONCLUSION

The COVID-19 pandemic has exposed weaknesses in the resilience of US manufacturing. To address these weaknesses, a rare confluence of strong, bipartisan political support has emerged.

We worry about the perils of inaction—a deep and prolonged recession could decimate domestic manufacturing capabilities for decades and erode resilience even further. An example would be the loss of US global market share in machine tooling as a result of the 1981-1982 recession. Now is the time for policy makers to act—and to act boldly.

The Trump Administration has confronted China over its mercantilist industrial policies and taken bold actions to keep China from fulfilling its desire to take global market share away from US manufacturers (as stated in its Made in China 2025 plan). Creating obstacles for strategic competitors may slow the erosion of US capabilities, but it will not enhance resilience. The United States needs to play offense, too. Our recommended policies aim to do just this.

Critical is the need for top-down commitment and providing information to point the way forward. The United States needs a 21st century roadmap for manufacturing, and we would argue that it currently has

none.

Maintaining historical capabilities matters, but nurturing nascent capabilities in future technologies is even more prudent–both in terms of resilience and cost-effectiveness. Nascent capabilities add to our knowledge base, and more know-how increases resilience. For example, continued advances in smart manufacturing will produce more agile firms. Investing in nascent capabilities is also more likely to be rewarded than investing in re-shoring of a capability that other nations dominate. It is akin to starting a race side-by-side with competitors versus behind your competitors—increasing the odds of success.

Importantly, a more resilient manufacturing sector is also a more competitive manufacturing sector. Most of our recommendations would improve the attractiveness of the United States to investors—including FDI. And a more competitive manufacturing sector creates strong positive externalities: across the entire economy, manufacturing contributes more to productivity growth (38%), international trade (60%), and private sector R&D (70%) than any other sector of the economy.

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[iv] S.3538, Protecting Our Pharmaceutical Supply Chain from China Act of 2020, 116th Congress, congress.gov.

[v] For a summary of how the pandemic has raised the cost of international trade, see "Covid-19's blow to world trade is a heavy one," *The Economist*, May 14, 2020. For a study showing that closed economies are more vulnerable to supply chain disruptions, see Bonadio et al. (2020).

[vi] For example, On June 24, the Senate Energy and Natural Resources Committee held a hearing on the impact of covid-19 on mineral supply chains. And on July 2, the House Small Business Committee held a hearing on supply chain resiliency. On July 23, the House Ways and Means Trade Subcommittee held a hearing on COVID-19 and manufacturing supply chains.

[vii] Congress has included provisions to incentivize US semiconductor fabrication in the National Defense Reauthorization Act. The Trump Administration has issued federal contracts for domestic production of essential medicines.
[viii] On July 5, the Biden presidential campaign website posted, "The Biden Plan to Rebuild U.S. Supply Chains and Ensure the U.S. Does Not Face Future Shortages of Critical Equipment."
[ix] The federal government has undertaken several initiatives to address issues of short-term liquidity for the vast majority of US manufacturers, which are small businesses: through the Paycheck Protection Program, which was part of the CARES Act; the Federal Reserve's Term Asset-Backed Securities Loan Facility; Economic Injury Disaster Loans, SBA Express Bridge Loans; and SBA Debt Relief (Prasad, E., 2020).
[x] Considerable academic and political debate has arisen over the relative importance of trade versus automation in explaining the drop in US manufacturing employment in the first decade of the 21st century. Recent research (Fort et al., 2018) concluded that both played a role.
[xi] In 2010, in a dispute with Japan over the Senkaku Islands in the South China Sea, China withheld the export of rare earth elements, disrupting global supply chains and causing a noticeable spike in prices (Carrell and Belton, 2019)
[xii] S.1317 in the 116th Congress, congress.gov.
[xiii] An exception is the Trump Administration's decision to have NIST assume a leadership role in the setting of international standards on artificial intelligence. We see this positive development as important but insufficient to ensure US leadership in smart manufacturing.
[xiv] H.R. 2900 in the 116th Congress, which can be found on www.congress.gov
[xv] The Biden campaign released its manufacturing plan on July 9, 2020. It emphasizes significant investments in R&D, infrastructure, procurement, and workforce training. It targets benefits to small and minority-owned businesses. It emphasizes 'Buy America' through changes in domestic and international law. And it describes the need to "bring back" critical supply chains to reduce US reliance on China and other nations.