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Reinventing Competitiveness

The Case for a National Manufacturing Foundation

by Sridhar Kota *and* Tom Mahoney

Too many, especially in Washington, these are halcyon days for America's economy. The stock market is at record highs and recent GDP growth has been robust. But look deeper. There's evidence that the structural foundations of America's economy may be shakier than at any time in recent memory. While the headline statistics look sanguine, we face serious challenges with respect to our ability to innovate and produce new products and processes. Yes, we are skillfully maximizing short-term earnings. But we are losing our capacity to generate genuine, long-term national wealth.

Offshoring across manufacturing sectors—including not just labor-intensive industries like apparel but also computers and telecommunications, consumer electronics, industrial equipment, and others—has resulted in the loss of five million manufacturing jobs since 2000. Manufacturing's output as a share of GDP was lower in mid-2018 than during the depths of the Great Recession in 2009. The recovery in manufacturing jobs since the recession has in large part been limited to just a few industries: transportation equipment, food, and fabricated metals.[1] Other sectors are still struggling to reemerge. Productivity growth, a key indicator of competitiveness, has been falling since 2005 and now is close to zero. Looking to our general competitiveness, the gap between finished goods prices and Chinese import prices continues to widen. Imports in all advanced manufacturing sectors continue to grow.

It's time for some soul-searching with respect to our economic future. Will we restore our ability to produce world-class products here in America? Will we invest in our capacity to lead innovation in the industries of the future? Or will we simply take solace in the comforting numbers from Wall Street, resigning ourselves to an economy focused on finance and services?

At the level of geo-economics, we need to ask some bigger questions: How have we, the most advanced technological power with the largest research budgets and many of the best universities, managed to lose our most essential assets for innovation and production? How have we managed to lose the economic foundations of our industrial heartland in the Midwest? How have other legacy industrial powers like Germany and Japan—with higher wages, higher energy costs, and stricter regulations—managed to weather competition from rising industrial powers more successfully? How have we allowed our medical supply chains and defense readiness to become utterly dependent on China?

Ask most Americans—regardless of ideology or geography—and they now recognize these fundamental problems. We need to strengthen our innovation and production capacities. If there's such a thing as a strategic necessity for the United States, it is manufacturing competitiveness. It is not only a cultural preference and an economic priority; it is also a requirement for military readiness and the survival of our supply chains in the face of foreign challenges.

How can we possibly meet this strategic necessity? In the wake of intensive offshoring and amidst increasingly sophisticated and well-financed rivals, how is manufacturing competitiveness attainable?

It is probably not too late to adopt a serious strategy to restore American innovation and manufacturing. But we need to engage in serious thinking about how to turn homegrown discoveries and inventions into products and processes that can create national wealth and help solve societal challenges from security to health to sustainability. We need novel approaches to innovation policy as well as new, focused investments in our production infrastructure, talent, and know-how.

Thankfully, there are cost-effective and politically viable solutions available. Specifically, we can start to catch up with other industrial powers by investing more in translating basic science research into useful innovation and production. This can start with the establishment of a National Manufacturing Foundation.

Innovation and Manufacturing are Inextricably Linked

Thirty-two years ago, as the Reagan administration entered its final year, industrial economists Stephen S. Cohen and John Zysman issued what was then an unpopular, though now a prophetic, warning: "If high-tech is to sustain a scale of activity sufficient to matter to the prosperity of our economy . . . America must control the production of those high-tech products it invents and designs." They continued, "production is where the lion's share of the value added is realized."[2]

This was heterodox thinking amidst the offshoring frenzies that began in the late 1980s. In many quarters, it still is. Too many U.S. political and economic leaders continue to believe that offshoring is not only profitable but also consistent with a sound national economic strategy. Manufacturing in China is cheaper, quicker, and more flexible, they argue. With China's networks of suppliers, engineers, and production experts growing larger and more sophisticated, many believe that locating production there is a better bet in terms of quality and efficiency. Instead of manufacturing domestically, the thinking goes, U.S. firms should focus on the higher-value work of innovation: "*innovate here, manufacture there*."

But today many Americans are questioning this perspective. From the White House to Congress, from union halls to university laboratories, there is a growing recognition that we simply can't afford the outsourcing paradigm. Once manufacturing departs from a country's shores, engineering and production know-how leave as well, and then innovation ultimately follows. We're now left in an unenviable situation: "*innovate there, manufacture there*." The offshoring of manufacturing has already transformed into offshoring innovation, too, when it comes to hardware.

Cohen and Zysman's warning about the perils of abandoning production has proven true. Start with the original offshoring craze, which centered on consumer electronics in the 1960s. The development of modern transistors, the establishment of standardized shipping containers, and the creation of inexpensive assembly lines in East Asia cut costs and created larger markets for televisions and radios, catalyzing the Asian manufacturing miracle. While American federal research investments in the decades that followed enabled the invention of game-changing technologies such as the magnetic storage drive, the lithium-ion battery, and the liquid crystal display, the nation had, by that time, already let go of consumer electronics manufacturing. Asia dominated.

Since the turn of the millennium, the offshoring trend has gone further. U.S.-based companies began contracting both design and product development work. China's entry into the World Trade Organization and Asian nations' major investments in workforce and production capacity accelerated these trends. A recent study conducted with input from 369 manufacturers found that U.S. firms across sectors have been moving R&D to China to be closer to production, suppliers, and engineering talent—not just to reap lower costs and more dynamic markets. An estimated 50 percent of overseas-backed R&D centers in China have been established by U.S. companies.

Innovation in manufacturing gravitates to where the factories are. American manufacturers have learned that the applied research and engineering necessary for new product introductions, design enhancements, and production process improvements are best done near the factories themselves. As more engineering and design work has shifted to China, many U.S. companies have a diminished capability to perform those tasks here.

Manufacturing matters—especially for a high-tech economy. While it's still possible to argue that the offshoring of parts, assembly, and final production has worked well for multinational companies focused on quarterly earnings, it is increasingly clear that offshoring has devastated the small and medium-sized manufacturers (SMMs) that make up the nation's supply chains and geographically diverse industrial clusters. While the share of SMMs in the total population of U.S. manufacturers has risen, their absolute numbers have dropped by nearly a hundred thousand since the 1990s.

The loss of America's industrial ecosystem has devastated industrial areas and undermined a core responsibility of government: providing for national defense. Recent analyses of the defense industrial base have identified specific risks to weapons production—fragile domestic suppliers, dependence on imports, counterfeit parts, and material shortages, for example. Meanwhile, despite tariffs, manufacturing imports continue to set records. Dependence on imports has virtually eliminated the

nation's ability to manufacture large flat-screen displays, smartphones, many advanced materials, and packaged semiconductors, so now we are unable to manufacture next-generation flexible displays and other emerging technologies.

This is to say nothing of the sociopolitical consequences and the very real human suffering that has come from the hollowing out of entire regional economies. Once vibrant communities in the so-called Rust Belt have lost population and income as large factories and their supporting suppliers have closed. The recent shuttering of the GM plant in Lordstown, Ohio, is just the latest example, resulting in the loss of roughly fourteen hundred high-paying manufacturing jobs. Nationwide, real wages have been stagnant for decades and, although the causes are debatable, surely the loss of manufacturing jobs has played a role.

In terms of America's long-term competitiveness, the biggest strategic consequence might be the loss of our ability to innovate—that is, translate inventions into production. We've lost the capacity to physically build what results from our investments in research. Without this ability, we cannot generate sufficient returns on our world-leading R&D investment. We cannot undertake the essential work of an advanced economy.

Manufacturing Myopia

While we as a nation continue to lead the world in terms of investment in basic research, we have lost the ability to engage in the kinds of process improvements that underlie innovation. We have largely lost our capacity for "learning by doing."

In seeking to understand the cause of our predicament, it's natural to look to the rising competitiveness of overseas industrial powers. But this alone ignores our own conscious policy choices that have contributed heavily to our current challenge. One of the clearest contributors is our policymakers' outdated approach to industrial policy—more specifically, their aversion to investment in results-oriented translational research.

In absolute terms, the federal government has been investing more and more every year in science and technology—averaging over $120 billion per year over the past ten years and over $150 billion last year alone (though as a percentage of GDP, spending is on a downward trend). Yet our trade deficit in advanced technology products has steadily grown to over $120 billion per year, and our overall manufacturing trade deficit grew to nearly $900 billion in 2018. Doing more of the same will not yield new results. Even if we double every program in the federal science and technology budget, it is

unlikely to reverse the deficits in advanced technology products—that is, it will not transform our ability to manufacture and export advanced technology products. The key is not how much we spend but what kinds of investments we make.

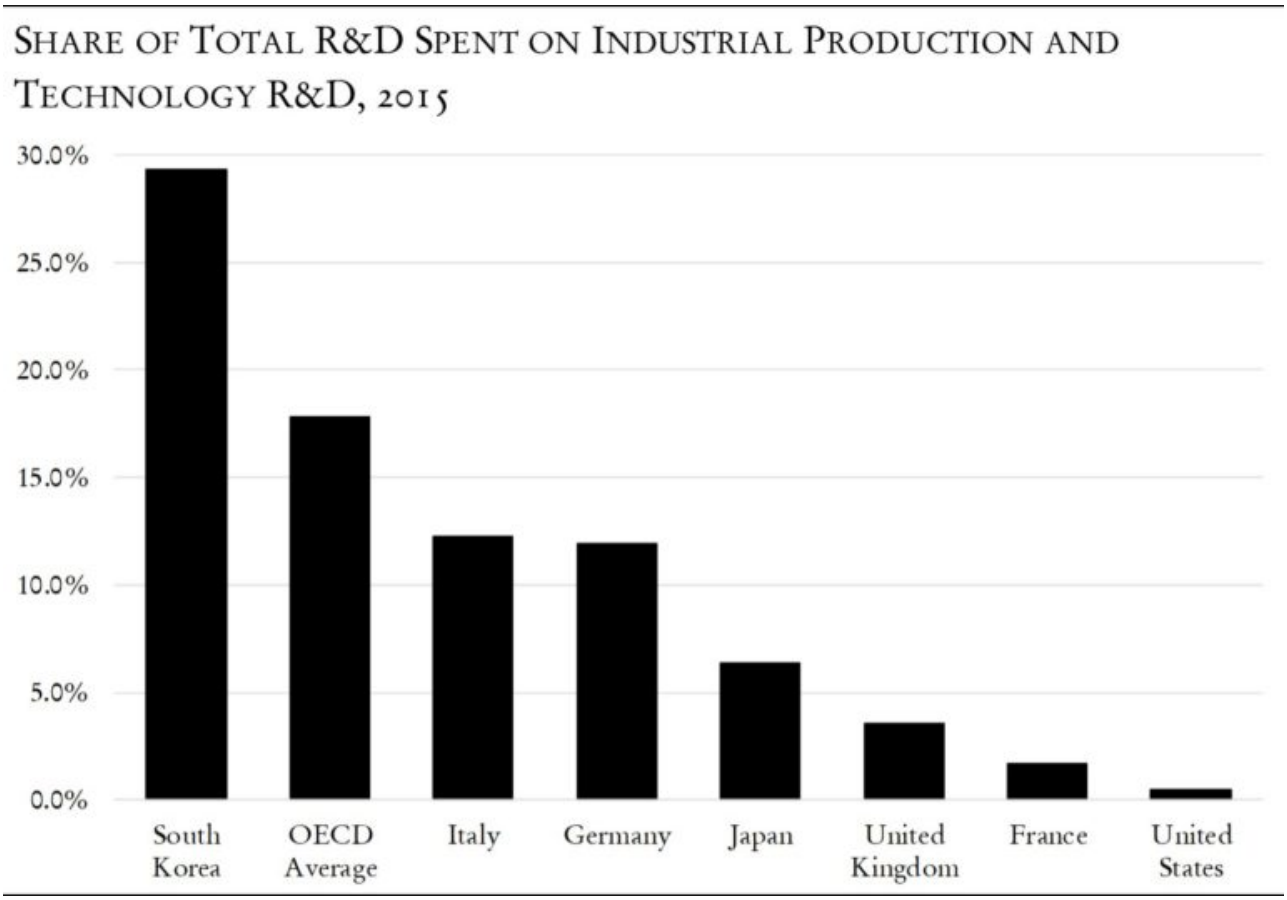
We are not investing in translating promising ideas from laboratories into products we can manufacture at home. U.S. venture capital firms have overwhelmingly emphasized software or biotech over manufacturing in recent decades. Many promising manufacturing enterprises are forced to look overseas for capital, production capacity, and the know-how to translate prototypes to commercial-scale products. Other nations are anchoring new industries by maturing inventions that originated in U.S. laboratories. These foreign competitors are now manufacturing products based on our homegrown ideas and then exporting the products back to the United States.

Take the case of lithium-ion batteries. While American federal research in the 1990s essentially established the feasibility of the technology, our leading battery companies opted out of volume manufacturing—not because of concerns about the costs of domestic labor, but rather because they did not want to commit to the high up-front investments, manage rapid product development cycles, and overcome limited access to markets. East Asian nations saw an opportunity. They supported their own firms with facilities, loans, and other assistance to win first-mover advantage. They were successful. Today, although the United States produces roughly 22 percent of the total global output of electric vehicle batteries, almost all of that is produced by Tesla's Gigafactory in partnership with Panasonic. Meanwhile, China is rapidly scaling up its production capacity. By 2021, planned increases are predicted to more than double global production capacity, mostly in China.[3]

Most U.S. policymakers have had a long-standing fear of any actions that might look like "picking winners." But this aversion has had a clear and unintended consequence: other countries are *picking our winners*. Other open, free-market economies are clearly able to pick winning technologies and make investments in transparent and unbiased ways that boost national competitiveness.

We need much more investment in "translational research." This means supporting not only basic research, but also the product design, engineering, and manufacturing process technologies that can turn a good idea into a real product. Science isn't the same as engineering. Putting a man on the moon had a lot to do with rocket engineering, not rocket science. Creating the internet had more to do with engineering than science. Being the best in the world in science is critical but not sufficient. Unless we invest in engineering and manufacturing R&D, our basic research will essentially continue to subsidize new product development in other countries.

Consider how other industrial powers structure their research investments: Japan invests about 7 percent of its national R&D budget on translational activities—turning basic research into meaningful new goods and processes. Germany invests around 12 percent. South Korea invests about 30 percent. The United States, by contrast, invests only 0.5 percent. Even with Japan's much smaller R&D budget, its total expenditure on translational research amounts to three times America's. Germany's investments amount to about six times total U.S. investments. South Korea's are nearly eight times what the United States spends.



Our failure to invest in translational research is only part of the challenge. According to recent research on 150 MIT-based hardware start-ups with access to the requisite talent and capital for initial R&D and proof-of-concept work, almost all were forced to go overseas—mostly to China—when they needed additional financing, production capabilities, and lead customers. They simply couldn't scale up production in the United States. This study was based on hardware start-ups formed between 1998 and 2008. This alarming state of affairs has undoubtedly become worse since then.

More ambitious policies and programs are clearly needed to better support our hardware start-ups. Federal purchase orders, for instance, can help firms access needed investments and loans, launch or boost production, and accelerate private investment.

Our national research investments are important. But they're not sufficient to support real innovation. We are permitting an ideological fear of "industrial policy" to dictate our economic future, with devastating consequences. Today, we are creating knowledge without creating national wealth or security.

The long-standing obsession with keeping government out of practical research is not only deeply counterproductive to national interests, it's also inconsistent. Two of the only American industrial sectors with dependably positive trade balances—aerospace and medical devices—enjoy their current status in large part because the U.S. government has played an unusually active role in nearly all aspects of their respective innovation ecosystems. The public sector continues to be deeply engaged in all stages of research, development, demonstration, deployment, regulation, procurement, and reimbursement in these fields for a variety of historical reasons. These industries have been some of the best financed and most farsighted in the United States during recent decades. This is no accident. In these areas, the U.S. government has not "picked winners." Yet it has taken strategic action to boost national competitiveness, job creation, and wealth creation. In short, it has done what a modern national government is supposed to do and what other advanced economies have often done better than we have.

Creating a National Manufacturing Foundation

If we want to maintain our status as an advanced economy, we need to think strategically about the future of U.S. industry. Tinkering with tax, trade, and regulation policy is unlikely to ensure that we establish the manufacturing industries of the future in this country. Large public companies are unlikely to abandon their fixation on short-term financial metrics, so the federal government must step in to make the strategic investments needed to rebuild the true fundamentals of our economy: our capacity to innovate and build.

There are promising models and practices already being pursued today that can help illuminate the path forward. Initiatives like the Hollings Manufacturing Extension Partnership (MEP), various Department of Defense (DoD) programs, Manufacturing USA institutes, and the National Science Foundation's Engineering Research Centers have all made—and continue to make—a contribution. Still, they have been insufficient to arrest the long-term negative trends. Many recent programs, such as the Department of Energy's Technology Commercialization Fund and DoD's Defense Innovation Unit, still only address peripheral elements of the problem. The nation's existing advanced manufacturing programs are scattered across multiple federal agencies, none of which has U.S.

manufacturing competitiveness as its core mission. The result, understandably, is a piecemeal approach to innovation and manufacturing. Recent history has made it clear that this approach does not work.

There's a better path. Rather than simply letting our best R&D outcomes languish in laboratories or be manufactured overseas by rivals, America should establish a National Manufacturing Foundation (NMF) to invest in developing promising technologies and anchoring their production onshore.

The NMF would address a series of critical needs in the U.S. innovation and production ecosystem.[4] This starts with the structure of federal policymaking: the new foundation would establish one "focal point" for manufacturing-related R&D in the U.S. government, helping to bring needed coherence to the interagency process.

The new NMF should be grounded in existing best practices for public policy. Just as the National Science Foundation (NSF) provides a clear and effective mechanism to support basic research by funding academic researchers through merit-based, competitive proposals, the NMF would focus on engineering, manufacturing, and hardware innovations, as well as supporting their success.

The NMF would have a five-part mission. First, it would help ensure that breakthroughs in research are actually manufactured in America. This means making focused investments to advance both technology readiness levels (TRLs) and manufacturing readiness levels (MRLs). Too many research results languish as prototypes in academic and national laboratories. Worse, many are manufactured abroad. The NMF should create a series of translational research centers (TRCs), strictly focused on advancing TRLs and MRLs, increasing the yield of commercially viable products from our innovation pipeline. The TRCs would be public-private partnerships based at, but not controlled or operated by, research universities. Each TRC would employ professional engineering and management staff to serve as systems engineers, project managers, market researchers, and private sector liaisons. They would be subject to clear metrics for gauging success and determining eligibility for continued funding. The TRCs would also have the flexibility to generate financial benefits from the technologies that they help to successfully reach commercial-scale production, either through equity stakes in start-up companies, a share of licensing income, or other mechanisms. Unlike most of the fourteen existing Manufacturing USA institutes, TRCs would not be specific to one technology. Instead, each TRC would have the appropriate expertise to identify various promising technologies emerging from academic research activities. TRCs would also have the connections with local industry needed to strengthen regional industrial clusters.

A further part of this vision is to restore geographic diversity to manufacturing by building on regional technical and intellectual strengths. Although TRCs would initially be established at leading research universities close to manufacturers, they would, over time, expand to groups of smaller universities across the country. An element of decentralization is key to this strategy: the purview of each TRC would flow from local decisions about the most promising technologies. At the same time, the new centers would be networked to avoid duplication of effort. Opportunities to share results, both successes and failures, would accelerate the learning process to the benefit of TRC operations and would encourage emerging technologies.

Second, beyond investment in translational research centers, the NMF would invest heavily in applied research in engineering and manufacturing process technologies common to multiple industrial applications. Examples include process technologies to scale metamaterials and high-entropy alloys, rapid reliability assessment of safety-critical and emerging technologies, the application of machine intelligence in varied production environments, and the use of technology to meet environmental challenges. The goal should be to get the most impact from our innovation to advance key national priorities. The NMF would seek to coordinate efforts throughout government to maximize such outcomes.

Third, the NMF would support new manufacturing investment funds, created through public-private partnerships, to increase the availability of capital for hardware start-ups and scale-ups. These funds would fill a gap in the venture capital markets and allow hardware start-ups to scale production in this country beyond pilot projects. These funds would directly complement technical support from TRCs with financial investments to rapidly increase the number and likely success of hardware start-ups. Several states already have small funds based on public-private partnerships that could serve as models. State investment banks, commonly used in Germany and other European nations, could also provide useful models.

Early procurement purchase orders are another important source of support for hardware scale-ups. The NMF would facilitate connections between these emerging technologies and companies and other government agencies, especially the DoD, for procurement contracts that would kick-start pilot production and beyond.

Fourth, the NMF would unlock new financial and technical support to help small and medium-sized manufacturing firms rebuild domestic supply chains. In particular, SMMs need help to accelerate their implementation of smart manufacturing technologies and to access the skills required to utilize these

technologies effectively. A combination of technical assistance and financial support—in the form of loans, grants, loan guarantees, and tax incentives—could augment existing technical support from the Manufacturing Extension Partnership and national laboratories.

Finally, the NMF would provide resources, typically in partnership with state and local governments, to build successful education and training programs for engineering. Nearly 60 percent of engineering graduates at the masters and doctoral levels from U.S. universities are foreign students, many of whom go back to their home countries. We need to increase graduate fellowships for qualified domestic students severalfold to create a pipeline of domestic engineering talent. Further, we need to invest in four-year engineering technology programs to increase the number of talented engineering graduates with the kinds of hands-on skills that industry now desperately needs. New NMF-based programming would draw heavily on existing best practices like the Oregon Manufacturing Innovation Center, which has brought together industry, higher education, and government to address near-term manufacturing challenges through applied research and advanced technical training. Likewise, the International Center for Automotive Research at Clemson University in South Carolina has developed significant research and training capacities, including K–12 outreach programs. This is a moment of opportunity for educating students to excel in advanced manufacturing industries. According to a recent survey, 37 percent of millennials perceive manufacturing as a high-technology career choice, notably higher than both Generation X (27 percent) and Baby Boomers (23 percent).

We should have no illusions, however: funding any new federal agency—especially a substantial new "foundation"—is a challenging proposition in the current era of partisan gridlock. But this approach shouldn't break the bank. To fulfill such a mission, the NMF should be funded at a level that amounts to approximately 5 percent of total federal R&D funding. An initial $1 billion investment could seed applied engineering and manufacturing R&D, TRCs, support for SMMs, and other key priorities. To put this in perspective, the U.S. Intellectual Property Commission has estimated that IP theft, counterfeit goods, and pirated software by Chinese actors costs the U.S. economy nearly $2 billion per day. Additionally, our manufacturing trade deficits amount to nearly $2.5 billion per day. There are serious costs to continued inaction.

Crucially, expenditures on the NMF must be direct, accountable investments in future competitiveness. To ensure that these investments will yield considerable future dividends to American taxpayers, clear metrics are essential. Specifically, evaluation should include factors like the number of technologies successfully reaching commercial production; private 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. The model must allow for timely assessments and course corrections to ensure that the NMF remains focused on the success of U.S. manufacturing.

Further, we should take aggressive action to ensure that any new innovation supports U.S. job creation and other economic development goals in this country. In addition to the support provided by the NMF, we should encourage domestic production through minimal license fees and government procurement contracts. On the other hand, to discourage offshore production, products or processes resulting from U.S. government-funded R&D should be subject to a licensing fee of 25 percent of revenues payable to the U.S. Treasury if those products are manufactured abroad, and imports based on the technology should be subject to a minimum 30 percent tariff. The objective is to create clear, meaningful incentives to manufacture new hardware technologies in the United States, though it should not matter whether the entity that scales the technology is headquartered in America or not. In fact, many Japanese and German companies, such as Toyota, Honda, Siemens, and BMW, to name a few, have continued to invest in U.S. manufacturing for decades. Such investments must be encouraged. It's time for proactive strategies to defend U.S. industrial competitiveness.

A Long-Term Strategy

All these proposals have a core objective: maximizing the return on the investments that we, as American taxpayers, are already making in federal R&D. Even in our current politics, this kind of policy shift should be possible. From the early days of his presidential campaign to his administration's imposition of tariffs, President Trump has consistently displayed a willingness to place national manufacturing competitiveness above the prevailing economic orthodoxies. While Republicans, and many Democrats, have long had an aversion to "industrial policy," it is increasingly clear that our past laissez-faire approach has amounted to "unilateral disarmament" for decades.

The first step toward renewal is recognizing the problem. While it's fine to celebrate positive headline numbers for the U.S. economy, we need a new focus on the fundamentals of our innovation and manufacturing economy. We need to rethink the meaning of economic success. It requires a social and cultural shift that is, thankfully, now underway.

Across the political spectrum, there's growing momentum for policy change. In June, Senator Gary Peters (D-Mich.) proposed the creation of a new National Institute of Manufacturing, taking inspiration from the National Institutes of Health. "This will be an executive branch agency that will

house our national manufacturing programs under one roof," he told the *Washington Post*. "NIH does a great job of coordinating a strategic vision for health care. Something similar should exist in manufacturing."

Senator Marco Rubio (R-Fla.), the chairman of the Senate Committee on Small Business and Entrepreneurship, has been increasingly critical of business executives for focusing too much on the next quarter and not enough on long-term innovation and capital investments. He has underscored that China's recent "Made in China 2025" plan should have been an alarm bell to U.S. policymakers and industry leaders. China 2025 represents precisely what's missing in America: a bold vision backed by serious resources. To counter China's rise as the world's preeminent industrial power, Senator Rubio is proposing new investment and coordination in manufacturing-focused innovation.

In an age when key electoral constituencies from both parties value domestic job creation and the revitalization of economically depressed regions, leaders across the ideological spectrum can emphasize bold action to boost advanced manufacturing. But policymakers need clarity on the scale and seriousness of this work. It's more than tax and trade policy. It's more than quick investment in research. To rebuild our economy on strong foundations, we need to restore what Harvard Business School's Gary Pisano and Willy Shih call the "industrial commons": our core production skills, infrastructure, and capabilities. This requires patience and lasting political will. It's a marathon, not a sprint. By investing in real solutions—translating our laboratory discoveries into meaningful new products and processes that create wealth and improve lives—we can transcend our current narrow focus on short-term stock prices or election cycles and start rebuilding the foundations of long-term prosperity.

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Notes

[1] Jaison R. Abel and Richard Deitz, "The (Modest) Rebound in Manufacturing Jobs," Federal Reserve Bank of New York, February 4, 2019.

[2] Stephen S. Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy* (New York: Basic Books, 1987), 8.

[3] Daniel Küpper et al., "The Future of Battery Production for Electric Vehicles," Boston Consulting Group, September 11, 2018.

[4] For a more detailed description of the national manufacturing ecosystem, the cycle of innovation, and the role of an NMF, see Sridhar Kota and Thomas Mahoney, *Manufacturing Prosperity: A Bold Strategy for National Wealth and Security*, MForesight, 2018.