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There is a case for believing that factories in the United States are making a comeback.

By Michael F. Molnar

This past February the federal government announced the two newest members of the nascent National Network for Manufacturing Innovation. While each industry-led institute has a unique charter, all share a common mission: to use applied research to scale up new factory-ready industrial processes and materials.

Engineering is a team sport and a contact sport, and NNMI embodies this. It creates a new space for industry and academia to meet and collaborate on precompetitive industrial challenges. Industry-led consortia compete for one-time federal investments. The winners must, at the very least, match this seed capital and provide enough value to become self-sustaining within five years.

The 60 initial members of the Lightweight and Modern Materials Manufacturing Innovation Institute, based near Detroit, matched the federal investment of $70 million. The 73 founders of the Digital Manufacturing and Design Innovation Institute, headquartered in Chicago, quadrupled their $70 million federal investment. If the growth of the year-old pilot institute on additive manufacturing, which now has more than 100 members, is any guide, the number of participants and their commitment will grow steadily.

Clearly, some businesses believe the future is bright for American manufacturing, and they are willing to back that up with their own resources.

Despite dire warnings a few years ago, U.S. manufacturing is not only alive but growing. U.S. output of manufactured goods is growing, exports are rising, and more and more firms are planning to expand or open factories in the United States.

In fact, many experts are optimistic about manufacturing's future. They see strong evidence that the United States is ready for a manufacturing renaissance—one that strengthens our ability to innovate, gives rise to new industries, and creates high-quality jobs. This is important not only to manufacturers and engineers, but to the United States economy as a whole.

LONG-TERM TRENDS

Most engineers have already heard the bad news. Between the start of 2001 and 2010, more than 64,000 factories closed their doors and one-third of all factory workers—5.7 million men and women—lost their jobs.

Some economists argue that U.S. factories have grown more productive, and that it takes fewer factories and workers to make the same amount of products. Yet many industries, including plastics, printing, wood and paper products, experienced declining output. As these plants closed, the ecosystem that nurtured them—small and medium-size firms with specialized skills—withered as well. With a weaker supply base, the remaining factories found it harder to compete effectively.

Meanwhile, many technologies invented in America migrated to overseas manufacturers. When it comes to promising new products, America is the world's idea factory. Americans pioneered everything from integrated circuits and computer networks to flat panel displays, electric cars, and photovoltaic cells. Yet the United States no longer mass produces many of these products.

So if the news is so bad, why am I optimistic?

After more than 10 years of bleak news about manufacturing, we are seeing signs of a turnaround. The United States has added more than 600,000 new manufacturing jobs since early 2010, the first sustained rise in 15 years.

Starting in mid-2012, the number of U.S. factories has grown for four straight quarters. While the numbers are not large, they represent the longest sustained increase in manufacturing facilities since 2000.

Manufacturing's share of the overall economy is also growing. According to a recent working paper by the International Monetary Fund, the current recovery

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marks the first time in 35 years that manufacturing not only bounced back but actually exceeded its percentage of the total U.S. economy before a recession.

Exports have been growing as well. In 2012, U.S. exports rose five times faster than those of other advanced economies and three times faster than emerging Asian nations, according to Bridgewater Associates, a large hedge fund. In 2013, when world trade slowed and exports from other advanced economies fell, U.S. exports continued to rise.

Additionally, U.S. trade deficits in advanced technology products are beginning to decline.

These trends, by themselves, do not define a manufacturing renaissance. But a close look at three critical trends—cost, risk, and energy—shows American manufacturing could prove competitive for decades to come.

The United States retains a leadership position in productivity that continues to ratchet down unit production costs. As a result, Bridgewater Associates has found that the United States manufacturing unit costs are lower than in Germany and other peer countries. Moreover, after adjusting for productivity, Bridgewater found U.S. unit costs are also lower than costs in such developing nations as Mexico and Brazil.

There is still a large gap in wages between the United States and Asian nations, but this gap is narrowing. Wages are rising throughout Asia. According to the International Labor Organization, they doubled between 2000 and 2010. Given higher U.S. productivity, many industries are likely to find the difference in total unit cost is shrinking, even before taking shipping and inventory costs into account, as Boston Consulting Group noted.

Long supply chains, where products may spend months in transit, often carry hidden risks, as well as time, management, and environmental costs.

By their very nature, extended supply chains increase risk. The 2011 earthquake off the Pacific coast of Töhoku and ensuing tsunami caused catastrophic destruction and loss of life in Japan. Less broadly known was the global manufacturing impact, as plants worldwide slowed or stopped when critical parts were not available. Many companies were surprised to learn their supply base was dependent on materials sourced solely from Japan.

Long supply chains may have several months of goods in the pipeline. This keeps companies from rapidly adding popular new features or correcting defects. Supply chains extended by time and distance make it difficult to correct quality problems not caught at the factory.

Companies increasingly factor in travel and management needed to keep far-flung supply chains moving smoothly and to ensure the protection of intellectual property. They must also deal with unexpected business risks, especially in societies without strong rule of law. It is not surprising, then, that a 2012 study by Harvard Business School professors Michael Porter and Jan Rivkin found that 56 percent of offshoring companies experienced unexpected increases in total landed costs.

In fact, more than half the manufacturing executives who brought new production back to the United States listed supply chain shortening as a top reason, according to Morgan Stanley. The Wall Street firm also found that 70 percent of executives surveyed planned to expand U.S. capacity within the next five years. Also, Boston Consulting found that nearly half of companies with more than $10 billion in sales were actively considering moving production from China to the United States.

Manufacturing is an energy-intensive sector, and over the past two decades, U.S. manufacturers have increasingly become leaders in industrial energy efficiency. Moreover, the United States is enjoying an unprecedented surge in energy production due to technological innovations in shale gas and oil

extraction. U.S. natural gas prices are now less than half those of Europe and one-third those of Japan and South Korea.

Natural gas and oil are direct inputs in many manufacturing sectors, including aluminum, chemicals, glass, iron and steel, paper, foundry products, fabricated metals, plastic and rubber products, and especially chemicals, where hydrocarbons provide both energy and feedstock materials.

In May 2012, the American Chemistry Council estimated that lower gas prices would generate 200,000 jobs in these eight industries, plus nearly 1 million jobs among industry suppliers and elsewhere in the economy. It projected that these industries would invest $72 billion in new capacity that would generate another 1.1 million jobs in construction and capital equipment production. These forecasts illustrate how access to low-cost energy could ripple through the economy and affect a broad range of industries while improving U.S. competitiveness.

Closing the cost gap, shortening supply chains, and taking advantage of lower energy costs are long-term trends that are likely to improve America's manufacturing outlook for years to come. But to create a true renaissance, one that grows new industries and adds millions of new jobs, we need to do more.

MANUFACTURING MATTERS

To fuel a true rebirth in innovation and economic growth requires investment in advanced manufacturing capabilities.

Let's start with innovation. Most engineers instinctively understand that a $1 billion computer chip factory is more valuable economically than a $1 billion warehouse complex. Why? Because even though manufacturers make up just 12 percent of the U.S. economy, they fund 70 percent of all private sector R&D, generate 70 percent of U.S. patents awarded to U.S. entities, and employ 60 percent of all R&D professionals.

Research, development, and design are intimately connected with product development and production—and proximity is essential. New ideas and insights for future improvements emerge as engineers and scientists struggle to resolve production problems, reduce costs, and improve performance. This type of iterative innovation enables manufacturers to build sustainable competitive advantages.

Bell Labs famously housed dreamers and doers under a single roof for this reason, and today Boeing has moved engineers to the production floor and Intel locates semiconductor plants near design facilities. As the U.S. National Research Council in its ongoing Making Value in America study and MIT's *Production in the Innovation Economy* report assert, manufacturing, design, and innovation are not independent pillars of business success, but are intimately linked.

A UC Berkeley economist found that the average manufacturing job supports 1.6 jobs outside of manufacturing. In advanced manufacturing, each job generates nearly five other jobs.

Moving production offshore isolates designers and engineers from their best opportunities for learning. If manufacturing moves offshore, eventually engineering—and America's ability to profit from its innovations—will follow.

Manufacturing also creates good jobs. Over the last decade, new hires in manufacturing earned an average of 38 percent more than new hires in non-manufacturing industries. And over a career, a manufacturing worker earns 17 percent more in wages and benefits than his or her counterpart in other sectors, according to U.S. Commerce Department data.

Yet this tells only part of the story. Today's factories are no longer the vertically integrated enterprises they were 50 years ago. They buy not only raw materials and components, but also specialized services once done by manufacturing employees. A plant, for example, might hire firms to clean heat exchangers, manage logistics, retrofit plumbing and wiring, maintain machinery, test materials or welds, model stress in molds, and even design its products. In Michigan, the fastest growing technical jobs are for automotive-related software and application developers. Most of these jobs are not classified as "manufacturing."

No wonder Enrico Moretti, a University of California, Berkeley, economist, found that the average manufacturing job supports 1.6 jobs outside of manufacturing. In advanced manufacturing, each job generates nearly five other jobs.

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Manufacturing plays a critical role in both innovation and jobs, and there is nothing inevitable about its decline.

Some economists, for example, argue that the rapid decline in U.S. manufacturing jobs is due to rising factory productivity. Yet U.S. manufacturing employment remained fairly stable—about 17.5 million workers—between 1965 and 2000 before declining by one-third between 2001 and 2010.

Productivity was rising throughout that entire 35-year period. And both Yale economist William Nordhaus and the Brookings Institution found that U.S. industries that boosted productivity the fastest were those most likely to increase employment.

In Germany and other developed countries, manufacturing's share of the economy declined, but key industries remained competitive against offshore competition. The reason, many assert, is simple: those nations treat manufacturing as an important part of their national economic infrastructure.

GLOBAL APPROACHES

Many governments offer direct support to manufacturers. China, for example, offers tax incentives, low-cost factory space, and export subsidies. Singapore entices top tech startups with direct investment, free or low-cost space, and subsidies for new science and engineering hires.

Germany partners with local manufacturers to train students from high school through graduate school. It supports more than 60 Fraunhofer Institutes, which provide high-quality, short-term R&D that small- and medium-size enterprises could not otherwise afford. It also hires graduate students and postdocs, usually for three to six years, before they find industry jobs.

Fraunhofer's relentless pursuit of applied research produces factory-specific solutions and a highly skilled R&D workforce. It strengthens the entire manufacturing ecosystem so manufacturers can compete on value rather than price. It is an important reason why more than 1,100 small- and medium-size German firms rank first or second in European or global markets for their products.

In the United States, innovation policies associated with manufacturing have a mixed reputation because they are sometimes associated with picking winners and losers.

Yet there is one area where innovation policy has had an undeniably positive impact: basic research. Long-term funding for basic science has created an outstanding culture of innovation and wealth creation in the United States.

We hope to kick off at least four more institutes this year. Each one will develop a platform technology that has the potential to change other industries.

Today, the United States leads the world—often by large margins—in nearly every metric used to measure research success. These include research funding, research paper citations, royalties and fees, and U.S. patents granted in biotechnology/pharmaceuticals, medical equipment, automation and control, and other technology areas, to name a few cited by the National Science Foundation.

While private industry dominates the "development" side of R&D, NSF finds that government-funded universities conduct most basic research. Federal support underwrote the basic science behind many of the vibrant industries pioneered in the United States. These include integrated circuits, computers, LEDs, flat screen displays, optical communications, nanotechnology, and biotechnology.

Yet many of these industries have moved abroad, to nations that invest in incentives and infrastructure to support them. Even startups in emerging technologies are being pulled overseas by aggressive government incentives, according to Elizabeth Reynolds of Massachusetts Institute of Technology, who discussed the subject in the November 2013 issue of this magazine. Reynolds and several colleagues studied the fortunes of 150 startups that had licensed technology developed at MIT.

The flow of manufacturing offshore is not inevitable. Thirty years ago, the United States faced the precipitous decline of its semiconductor industry in the face of better funded Japanese competitors. In 1987, the federal government and 14 U.S. semiconductor manufacturers founded SEMATECH to regain lost competitiveness by addressing common manufacturing problems. The Department of Defense invested

a total of $848 million, which was matched by industry. By 1996, SEMATECH had become self-sustaining and had begun to expand—and its now robust members had returned nearly $35 billion in tax revenue to the federal government. Today, SEMATECH is widely credited with retaining American leadership in semiconductors and attracts members from around the world.

SEMATECH was one of the models we looked at when creating the National Network for Manufacturing Innovation. We also looked at best practices from Germany, Japan, Canada, and other developed nations that compete on know-how rather than cost. We found much to build on, while leveraging such unique American strengths as our world-renowned research universities, industry-leading manufacturers, and entrepreneurial culture.

Like SEMATECH, NNMI institutes do not pick winners or losers. The institutes are viable only when private companies are willing to commit significant matching funds of their own. Each institute will have its own specific focus, and must line up broad-based industry funds to become self-supporting within five to seven years.

Like the Fraunhofer Institutes, NNMIs will develop factory-ready technologies for their target industries' entire manufacturing ecosystems. They will also serve as "teaching factories," training R&D professionals to transform research into sustainable competitive advantage and establishing a workforce familiar with these new technologies.

The NNMI program seeks to transform an unquestioned American strength—pioneering R&D—into new growth industries.

Our first four institutes focus on digital manufacturing and design, lightweight materials, power electronics, and additive manufacturing. We hope to kick off at least four more institutes this year, including the Advanced Composites Manufacturing Institute. Each one will develop a platform technology that has the potential to change other industries. They could help the United States take the lead in products as varied as ultra-efficient automobiles, high-efficiency appliance motors, customized production, and personalized yet affordable prosthetics.

The United States invests more money in research than any other nation. It is time to receive full value from this investment by making what we invent.

The National Network for Manufacturing Innovation has already drawn bipartisan support in Congress. It is only one of several proposals to improve the competitive position of U.S. manufacturing. The Obama administration has proposed reforming the tax code to reduce tax rates and eliminate incentives to build factories abroad. There is strong bipartisan support for improving and certifying technical and vocational training in community colleges, as well as certifying the training of returning veterans and upgrading our national infrastructure.

U.S. manufacturing is poised for a turnaround. The wage gap with foreign competitors has narrowed, U.S. companies have a greater appreciation of the hidden costs of long supply chains, and energy prices have been falling.

There is growing awareness in the importance of manufacturing as a means to expand employment and create wealth—but also to stimulate new rounds of innovation. This special role in the U.S. innovation ecosystem is why a manufacturing renaissance benefits all sectors.

This is why we must invest for the long-term in U.S. manufacturing. Industry's "golden age" has not come and gone. We have the knowledge and the path to ensure that the best of American manufacturing is yet to come. **ME**

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