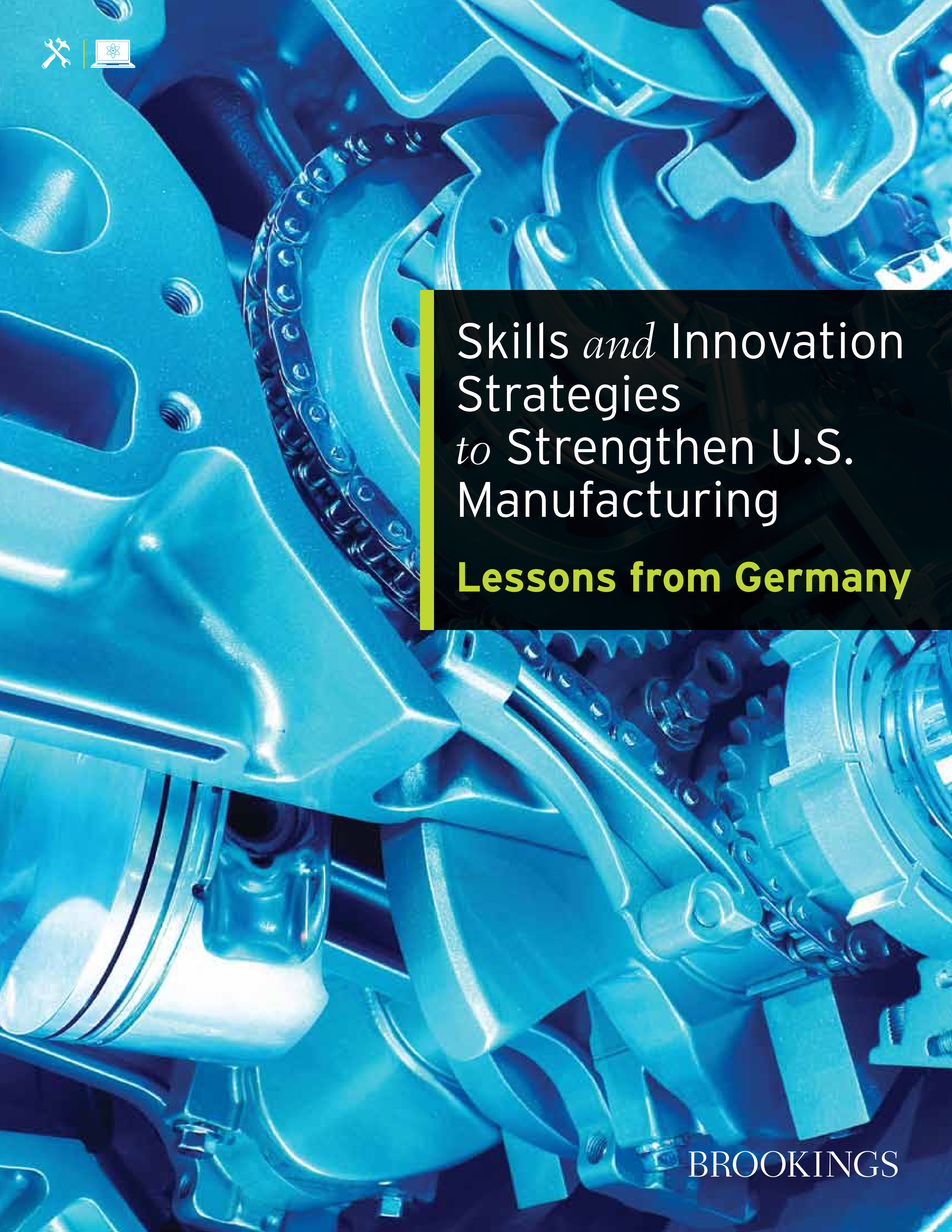


Skills *and* Innovation Strategies *to* Strengthen U.S. Manufacturing

Lessons from Germany

BROOKINGS

Skills *and* Innovation Strategies *to* Strengthen U.S. Manufacturing

Lessons from Germany

GLOBAL CITIES INITIATIVE
A JOINT PROJECT OF BROOKINGS AND JPMORGAN CHASE

JOSEPH PARILLA, JESUS LEAL TRUJILLO, AND ALAN BERUBE

EXECUTIVE SUMMARY

Faced with stagnating wages for most Americans, business, civic, and political leaders across the United States are rediscovering manufacturing as a source of good jobs and lasting economic growth. In an era of unrivaled global competition, however, revitalizing the U.S. manufacturing sector will require a renewed commitment to public-private-civic partnerships that deliver on the key driver of industrial competitiveness: a highly trained workforce that can use technology to translate basic and applied research and development (R&D) to large-scale commercial innovations.

"Three key takeaways—regional collaboration between public, private, and civic actors; targeted institutional intermediaries that address market failures; and incentive-based investments to support small and medium sized businesses—should guide U.S. actors seeking to adapt German skills and innovation best practices to support manufacturing."

However, in both skills training and technological innovation, U.S. policies to support manufacturing have not matched the sector's evolution from one dominated by massive, vertically-integrated companies to a more distributed mix of small, medium, and large firms. In this new environment, research and development, particularly applied research, and skills training are underprovided in the market because individual firms fear they will not recoup their full investment if a competitor reaps the benefits of a new innovation or poaches a well-trained technician.

Other advanced nations have done a better job of addressing the market failures that inhibit industrial competitiveness. Germany is an oft-cited example of an advanced economy that has been able to sustain manufacturing as a relevant source of employment, growth, and exports. Manufacturing in Germany accounts for 20 percent of employment, nearly twice the share as in the United States, and generates 22 percent of national GDP and 82 percent of total goods exports. German manufacturing succeeds in the global marketplace even as the sector pays higher average wages than in the United States.

Germany's manufacturing sector benefits from a concerted federalist policy effort to support clusters of globally competitive manufacturers, particularly its small and mid-sized *Mittelstand* firms, through powerful **public-private collaborations on applied research to support innovation** and a **dual model of vocational education** to sustain a highly trained workforce.

While recognized as global best practices, these models cannot be imported wholesale into the United States. Rather, three key takeaways—***regional collaboration*** between public, private, and civic actors; ***targeted institutional intermediaries*** that address market and coordination failures; and ***incentive-based investments*** to support small and medium sized businesses—should guide U.S. practitioners and policymakers seeking to adapt German skills and innovation best practices to support manufacturing here at home.

In November 2014 the Global Cities Initiative, a joint project of Brookings and JPMorgan Chase, brought 40 U.S. business, civic, and government leaders to Munich and Nuremberg, Germany to learn more about the German model for manufacturing competitiveness. For U.S. practitioners and policymakers interested in applying German best practices in their own places, this paper serves to document the key discussion themes and potential lessons from that trip. It provides a brief overview of the current state of manufacturing in each country (Section I), the German systems for innovation (Section II) and vocational education and training (Section III), and concludes with examples of how U.S. leaders are applying the most successful elements of these German systems to the American context (Section IV).

I. MANUFACTURING IN THE UNITED STATES AND GERMANY

THE STATE OF U.S. MANUFACTURING

U.S. manufacturing stands at a crossroads.

The first decade of this century saw one in 10 U.S. factories close, a one-third decline of the manufacturing workforce, and skyrocketing trade deficits. These setbacks, decades in the making, exposed serious weaknesses in U.S. industrial competitiveness.[1]

Yet recent trends signal a tentative optimism. Manufacturing has rebounded in the post-recession period: Since 2009, the sector has grown faster than the economy as a whole, and since 2010 manufacturing has created nearly 800,000 new jobs.[2] And recent global dynamics—from rising labor costs abroad to new energy sources at lower prices and technologies at home—present new cost advantages over Asia and Europe and suggest that the sector's recovery may not simply be cyclical.[3]

For the country to seize on manufacturing's recent momentum, however, it must rebuild what Harvard Business School researchers Gary Pisano and Willy Shih call the "industrial commons"—the concentrations of research institutions, skilled workers, and suppliers that form the backbone of America's most competitive industrial hubs.[4] Manufacturers thrive when they draw on the collective knowledge and spillovers from clusters of similar firms and deep pools of labor, which in turn are anchored by supportive institutions such as universities, research institutes, community colleges, and industry consortiums.[5] These networks, which concentrate in regional economies, are together responsible for the key driver of industrial competitiveness: a highly trained workforce that can use technology to translate basic and applied research and development (R&D) to large-scale commercial innovations.[6]

Experts point to several factors to explain U.S. manufacturing's decline, including macro factors such as tax and trade policy, but insufficient investments in people and technology partly explain why the sector became susceptible to global competition over the past several decades. The further opening of the global trading system; the effective doubling of the globally connected labor pool; and sustained advances in information, communication, and transportation technologies allowed companies to distribute different stages of production where they could be completed most efficiently and effectively.[7] To remain profitable in this new environment, American companies needed to either cut costs or become more innovative. Many U.S.-based producers chose the former, offshoring their operations and outsourcing any responsibilities deemed non-essential to their supply chain.[8] This phenomenon, coupled with automation, shrunk the average manufacturing establishment size from almost 70 employees in the late 1970s to 41 employees in 2006.[9]

The downsizing and offshoring of American manufacturing firms disrupted the longstanding model for innovation in manufacturing. Since the 1960s, the U.S. government has limited its involvement in innovation to the financing of basic research through universities, research institutions, and general research grants, while the private sector transformed these basic knowledge inputs into new products, technologies, services, and business models.[10] This model worked well for American manufacturing because highly integrated companies developed R&D capabilities in-house that allowed them to translate pure scientific knowledge into new products (e.g. Bell Labs, PARC, etc.).[11] Significantly, technological breakthroughs by large manufacturers also spilled over to small and medium-sized enterprises (SMEs), allowing them to participate in new industries or to innovate within existing supply chains.[12]

However, the offshoring of production to cheaper locales separated it from manufacturers' domestic R&D operations.[13] These cost-cutting moves discounted the fact that innovation occurs most successfully when R&D and production are tightly linked, ideally co-located so engineers and production workers can make adaptations and bring products to market more quickly.[14]

The offshoring of different manufacturing industries not only affected the innovation capacity of firms within one industry, but also diminished the positive spillover effects that many of these R&D activities had on other industries.[15] In this way, offshoring diminished the competitiveness of multiple industries at once.[16] Even when American researchers develop radical innovations, defined as the creation of a new industry due to technological or scientific breakthrough, U.S. manufacturers are often unable to bridge the "valley of death" between the basic research phase and industrial production due to lack of capital and other key resources.[17]

"Revitalizing U.S. manufacturing will require renewed public-private-civic partnerships that deliver the workforce and technologies demanded by 21st century industry."

The valley of death widens without support for pre-competitive (applied) research, defined by Competence Centre for Materials Science and Technology as the "middle ground of focused cutting-edge research that lies between fundamental basic research conducted mainly in universities and proprietary research performed in corporate laboratories."[18] For instance, U.S. companies developed the technology behind semiconductors, but more foreign manufacturers (at times buoyed by government support) attracted their production and have since improved on the original innovation, a process that helps them accrue significant benefits of the late technology cycle.[19] The trade balance for semiconductors has fallen dramatically over the last decade, with the United States retaining a slim trade surplus of $1.6 billion as of August 2014, as compared to a $24 billion surplus in 2006.[20] The United States' core innovative competencies—world-class universities, entrepreneurial dynamism, and a strong venture capital system, among others—have not been enough to maintain its manufacturing market share in even the most high-tech industries.

The changing structure of U.S. manufacturers also altered the hiring, training, and retention of industrial workers. As with R&D, the responsibility of training American manufacturing workers historically rested with a group of large, vertically integrated companies. In the post-war period, young people flocked to manufacturing with the realistic expectation that one firm could offer them a stable career with advancement potential. In turn, employers invested long-term in their employees with the realistic expectation that a more productive workforce would benefit the company's bottom line, not a competitor's.[21]

Facing new cost constraints, manufacturers had less capacity to train their workforce internally. At the same time, fewer young Americans viewed manufacturing as a promising career as automation and global pressures reduced job certainty and held back wage growth.[22] In a world of short tenure, high turnover, and flat or declining real wages, workers hesitated to invest in their own skills, the education system moved decisively away from providing vocational pathways, and firms had less incentive to train their employees for the long term, choosing instead to search for experienced workers in the marketplace.[23]

"Manufacturing in Germany accounts for 20 percent of employment, nearly twice the share as in the United States, and generates 22 percent of national GDP."

For several decades the supply of technical workers remained healthy due to the long-run decline in manufacturing employment demand and then the Great Recession's acute rise in layoffs.[24] Now, however, as manufacturers recover and ramp up hiring they are faced with an impending wave of baby boomer retirements, and are concerned they do not have a sufficient pipeline of talent in high-demand occupations that require significant levels of technical expertise.[25] As employers turn to the education system, there is a clear need for manufacturers and educators to work together to rebuild training pipelines, but existing policies and practices are ill-equipped to recreate such pipelines at scale.[26] At the same time, the U.S. youth unemployment rate stands at 14 percent, causing policymakers to question current approaches to helping young people transition from school to work.[27]

WHY GERMANY?

Germany offers an example of an advanced economy that has been able to sustain manufacturing as a relevant source of employment, growth, and exports. Manufacturing in Germany accounts for 20 percent of employment, nearly twice the share as in the United States.[28] Manufacturing generates 22 percent of total German GDP and 82 percent of German goods exports.[29] In stark contrast to the United States' $667 billion manufactured goods trade deficit, Germany's trade surplus in manufacturing is about $425 billion.[30]

These strong labor market, growth, and trade outcomes reflect Germany's ability to infuse technology into its manufacturing sector to remain globally competitive. Medium and high-technology industries account for a larger share of the sector's total output in Germany (58 percent) than in the United States (42 percent).[31] Yet a cross-national comparison reveals that Germany invests only marginally more in public R&D as a share of its economy; U.S. universities exhibit much greater scientific impact; and entrepreneurship (as measured by new firm creation) is actually lower in Germany.

Three statistics may help explain Germany's advantage in manufacturing. First, 86 percent of private-sector R&D occurs in manufacturing, a much higher share than the 64 percent in the United States.[32] Second, Germany translates research into

Table 1. Germany vs. the United States on Key Economic Indicators

	Germany	United States
Economic Output		
Share of GDP in Manufacturing	22%	12%
Share of Manufacturing GDP in Medium & High-Tech Manufacturing	58%	42%
Trade		
Total Exports as a Share of GDP	52%	14%
Share of Merchandise Exports in Manufacturing	82%	62%
Trade Balance in Manufactured Goods	$425 billion	-$668 billion
Innovation		
Total Researchers Per 1000 Workers	8.22	8.08
R&D Expenditures as a Share of GDP	2.98%	2.79%
Share of Corporate R&D in Manufacturing	86%	68%
Number of Top 50 Universities in Leiden Impact Rankings	0	39
Patents per 1000 Researchers	53.03	38.74
New Firm Entrants as a Share of Total Firms	7.90%	8.50%
Workforce		
Share of Employment in Manufacturing	20%	10%
Average Hourly Compensation in Manufacturing	$45.79	$35.67
Share of Graduates in STEM Fields (OECD Rank/36)	3	33
Youth Unemployment Rate	8%	14%

Source: World Bank and OECD national accounts data; OECD Science and Technology Indicators; CWTS Leiden Ranking; OECD Entrepreneurship at a Glance data; U.S. Bureau of Labor Statistics.

new products and technologies more effectively. In 2011, Germany produced 53 patents per 1,000 researchers, compared to 39 patents per 1,000 researchers in the United States. Finally, Germany's ability to translate research into new products derives from its rich base of graduates in STEM (science, technology, engineering, and mathematics) fields. In a ranking of 36 OECD countries on their share of graduates in STEM fields, Germany ranked third, well ahead of the United States at 33rd. In 2012, more than 800,000 German students participated in an apprenticeship program in the manufacturing sector.[34] Partly as a result of these apprenticeship programs, manufacturing companies do not suffer as dramatically from shortages in the supply of skilled technical workers, and employees receive valuable qualifications that translate into high wages. The average compensation for a manufacturing worker in Germany is $46 per hour, 28 percent more than in the United States.[35]

In these ways Germany offers an illustrative model for industry growth. Many factors contribute to Germany's strong global position in manufacturing and trade, including a series of economy-improving federal reforms during the 2000s as well as an undervalued currency.[36] But Germany also benefits from its concerted federalist policy effort to support clusters of globally competitive manufacturers, particularly its *Mittelstand* firms, through powerful public-private collaborations on applied research to support innovation and a dual model of vocational education to sustain a highly-trained workforce. ■

Innovation—the act of taking an idea or technology and transforming it into a sellable product or process—remains the key to raising the living standards of any advanced economy.[37] Manufacturing's most important economic contribution, therefore, may be its role as a significant source of innovation. A two-year study found that manufacturing firms were more likely to create new products and processes than non-manufacturing firms.[38] In turn, innovation remains a critical input to manufacturing, especially as information and digital technologies such as robotics, advanced materials, and complex software systems increasingly pervade the sector.[39]

German manufacturers have been particularly successful in translating research into new products and technologies due to a dense network of universities, public research organizations, state and federal governments, industrial research organizations, and foundations (Figure 1).[40] Organized by a highly-coordinated federal technology strategy, these institutions work collaboratively and across multiple levels of government to support manufacturing through basic scientific research, applied industrial research, innovation incentives, and targeted strategies to develop industry clusters and new technologies.

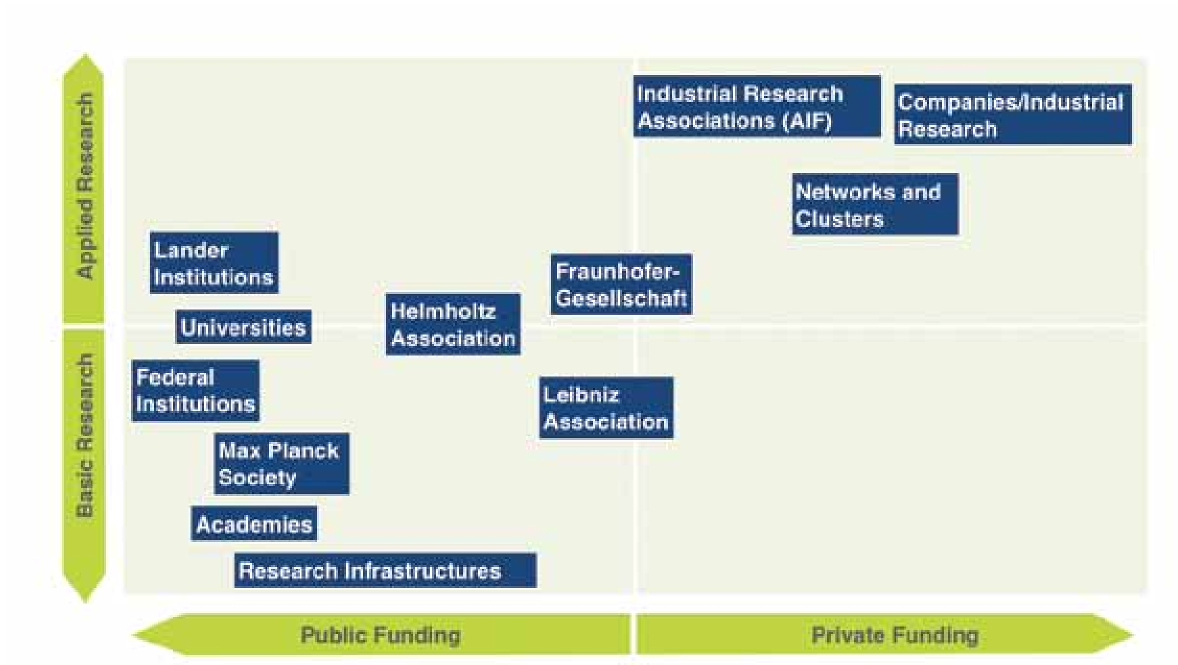
BASIC RESEARCH—THE PLATFORM FOR INDUSTRIAL INNOVATION

Germany employs a strong platform for basic scientific research that resembles the institutional structure in the United States. Basic scientific research occurs in a plethora of German institutions, including:

- A large network of universities and applied science universities;
- National laboratories such as the Helmholtz Association (the equivalent of the U.S. Department of Energy's National Laboratories). As Germany's largest research institution, the Helmholtz Association serves as the umbrella organization for different research entities in earth sciences, energy, aeronautics, space and transport, health sciences, advanced materials, IT, and particle physics;[41] and
- Other research associations such as the Leibniz Association and the Max Planck Institutes. The Max Planck Institutes are one of the most prestigious research institutions in the world and focus on fields such as astronomy and astrophysics, complex systems, genetics, neuroscience, biosciences, chemistry, material science, computer science, particle and quantum physics, and microbiology.[42]

Basic research matters for manufacturing in a couple of ways. First, as the main producers of pure scientific knowledge, basic research institutions provide the theoretical foundation for applied research and discover new research fields with potential application to industrial use.[43] Second, basic research laboratories are a vehicle for the federal government to shape the priorities of its broader industrial technology policy through grants and research bonuses.[44]

Figure 1. Germany's Innovation System



Source: Brookings modification of graphic from "Research in Germany" portal, the central information platform of the initiative to "Promote Innovation and Research in Germany" by the Federal Ministry of Education and Research (BMBF).

APPLIED RESEARCH AND THE FRAUNHOFER SOCIETY

Where Germany's innovation system begins to differ from the United States' is in its network of applied research institutes. The Fraunhofer Society (Fraunhofer) is perhaps Germany's best known and most important applied research institution. Its purpose is to help translate basic research and nascent technologies into viable commercial products. Fraunhofer has 67 institutes and 23,000 employees in Germany as well as an international presence that includes seven U.S.-based centers.[45] Each institute cultivates a distinct specialization (e.g. applied polymer research, electric nanosystems, etc.) which fall under broader industries such as microelectronics, materials and components, production, surface technology and photonics, life sciences, information technology, and defense.[46] Approximately 70 percent of Fraunhofer's revenue is generated by contracts with industry and public institutions; state and federal governments contribute the remaining 30 percent.[47]

Put simply, Fraunhofer helps manufacturers bridge the valley of death, which often occurs at a stage of production development where the potential return on investment is high but equally high levels of uncertainty prevent firms from investing significantly in R&D. This is especially true for small and mid-sized companies, where lower revenues at times prohibit R&D. Fraunhofer reduces firm uncertainty in a key way. Thanks to its vast network of researchers, which covers virtually all areas of science, Fraunhofer's scientists can interpret complicated experimental findings and their consequences in ways that lead to practical applications for the private sector.[48] The contracts they establish with firms, therefore, serve as a research subsidy: Fraunhofer charges companies to cover just the costs of developing a project, but do not include the historical costs Fraunhofer incurred to develop the institutional knowledge it uses in the project. Fraunhofer undertakes anywhere between 6,000 and 8,000 industry projects per year, including famous inventions like the MP3.[49] The size of these projects varies significantly, ranging from less than €1,000 to several million euros.[50]

Fraunhofer also offers flexibility to manufacturers. Firms may not have the in-house capabilities or resources to address a particular technical challenge so they contract with Fraunhofer to perform pre-production research or develop a prototype. At other times, Fraunhofer simply allows private sector researchers access to specialized machinery to test prototypes and conduct advanced research.[51] Often Fraunhofer and industrial scientists work hand-in-hand on a project, promoting the mobility of scientists between universities and the industrial world.[52] Research suggests that, through these myriad supports, Fraunhofer has been the most prominent actor in Germany's promotion of firm-level R&D.[53]

In addition to supporting individual firms, Fraunhofer helps consolidate regional clusters by establishing industry or technological specializations within its individual institutes.[54] These specializations typically coincide with the industrial base of the region in which they reside and complement the research expertise of other research institutions and universities. Together, these networks form the backbone of a regional innovation ecosystem, but collaboration is not limited to only within the region. The Fraunhofer network has also facilitated "long distance" collaboration, which occurs when the closest Fraunhofer facility is not specialized in the technology of interest for a particular firm.

The German Federation of Industrial Research Associations are a less discussed but still relevant part of Germany's applied research ecosystem. They provide a series of services to support the advancement of R&D in SMEs by promoting, alongside the federal and state governments, relevant research areas for the industry.[55] They diffuse relevant information among SMEs, directing many firms to the right research institutions, and serve as project managers for joint research projects. They also facilitate the pooling of resources to avoid the problems of funding shortfalls, personnel or training gaps, and technology and equipment inadequacies.[56]

INNOVATION INCENTIVES

The collection of organizations involved in supporting innovation in manufacturing—research centers, universities, firms, and research consortiums—benefit from a robust offering of incentives from Germany's federal and state governments. The system has multiple tools to foster innovation, which translate into multiple options for companies to access and implement R&D, thus maximizing the likelihood they will adopt new technologies.

The federal government, via the Federal Ministry for Economic Affairs and Energy (BMWi), provides direct funding for SMEs through the Central SME Innovation Program (*ZIM-Solo*). Companies that have fewer than 250 employees can apply for a non-refundable research subsidy to cover expenses associated with the development of R&D projects, either in-house or by a research institution, as well as consulting services for the implementation of new processes and technologies. The funds, up to €350,000, can cover up to 55 percent of R&D activities and up to 50 percent of the consulting services.[57]

State governments also have a wide range of tools to promote innovation. State-level funding facilitates collaboration between universities, other research institutions and firms. In Bavaria, the Ministry of Economic Affairs, Infrastructure, Transport and Technology provides funds for joint research through programs such as the New Materials Development Program, Microsystem Technologies Program, and Information and Communication Technologies Program.[58]

State governments also provide innovation vouchers to SMEs to support their R&D activities. Innovation vouchers allow firms to conduct additional research themselves or redeem the voucher at a research institution of their choosing. The effect of the innovation vouchers is twofold. First, they promote the participation of SMEs in R&D activities that, due to high financial cost and uncertainty on the return of the investment, would not have occurred otherwise. Second, the vouchers also provide additional funding for research institutions, particularly for applied research organizations, to conduct risky research at a lower cost.[59] The state of Bavaria offers innovation vouchers through its Program for the Introduction of Technologies (BayTP), while also offering loans and capital for recently created start-ups in high-tech industries.[60]

SMART FEDERALISM ORGANIZED AROUND TECHNOLOGIES AND REGIONAL CLUSTERS

Germany organizes basic research, applied research, and firm-level incentives around a concerted federalist strategy that sets general policies and research guidelines, establishes funding levels, decentralizes administrative tasks, and defines priority technologies, regions, and clusters.

Germany's federalist strategy begins with its national innovation policy, the High-Tech Strategy 2020 (HTS). The HTS provides incentives to increase collaboration between science and industry and, in doing so, sets the framework for basic and applied research. The strategy provides €15 billion for research related to cross-cutting technologies that have broad applicability across multiple manufacturing industries, dispensing the funding in a competitive process that requires collaboration among public, private, and civic institutions.[61] Similarly, the Federal Ministry for Economic Affairs and Energy's ZIM-Coop scheme provides funding for R&D projects undertaken by several companies or between a firm and research institutes.[62]

Germany's strategy also recognizes that innovation typically occurs amid regional clusters of research institutions, firms, and universities. In 2007 the Federal Ministry of Education and Research launched the Leading-Edge Cluster Competition, a research contest that provides funds of up to €40 million to five clusters, selected every 18 months, to develop key technologies that have the potential to impact an entire supply chain.[63] The initiative asks for joint proposals by the private sector, research institutions, and universities to develop new technologies, products, and processes. These programs are not "top-down" in the traditional sense. Rather, they decentralize administrative and managerial tasks to project management institutions well-versed in the innovation needs of firms; a structure that reduces duplicity of efforts, minimizes bureaucracy costs, and improves project management.[64] As of 2014, three different cohorts of five clusters each have been selected, all revolving around one key technology and involving a regional component. Preliminary results show that participating SMEs were more likely to conduct R&D.[65]

In many occasions federal funds complement state-led innovation initiatives. For example, two clusters selected as part of the Leading-Edge Cluster Competition also received support from the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology's Cluster Offensive. The funds provided by the state government were utilized to cover expenses not included or sufficiently funded in the Leading-Edge Cluster Competition funds.[66]

The main takeaway: Germany's innovation system offers several types of resources and incentives for different actors with a significant role in the innovation process. This multi-targeted and multilevel approach increases the likelihood that firms will engage in R&D, fosters collaboration between researchers and the private sector, and promotes accumulation of research and technical knowledge within manufacturers and the regional economies in which they reside. Thanks to this organized effort, a wide variety of firms, particularly Germany's *Mittelstand*, have been able to reap the benefits of public and private research to outperform international competitors.[67]

"Germany's comprehensive innovation strategy helps firms engage in R&D, fosters collaboration between researchers and the private sector, and enhances the competitiveness of manufacturers and the regional economies in which they reside."

STUDY TOUR: EXAMINING GERMANY'S INNOVATION MODEL AT ESG[68]

The Global Cities Initiative study tour examined Germany's multi-faceted innovation system through a visit to the mid-sized industrial software house ESG in Munich and a workshop between leading U.S. and German practitioners and policymakers. Following a tour of ESG's software simulators, a series of executives at ESG and public officials described the purposeful German approach to technology innovation. Participants were impressed by the rigor of ESG's internal "road-mapping" of the direction of the global systems software business and its self-funded research programs, which allow employees to apply for three-week mini sojourns to try out new ideas in preparation for more substantial investigations.

Buttressing ESG's company-level efforts are a multi-dimensional set of supportive institutions and activities. Jurgen Niehaus, the CEO of the German "competence cluster" SafeTrans, noted how his industry association supports R&D activities in ESG's embedded systems industry through a variety of workshops, exchanges, and outlook exercises. Florian Holzapfel, the chairman of the Department at Flight Dynamics at the nearby Technical University of Munich, described a university heavily oriented toward applied technical work on avionics and the dynamics of aerial platforms. And Manfred Wolter from the state of Bavaria's technology ministry detailed a carefully structured suite of sub-national programs aimed at strengthening the region's research infrastructure, providing R&D funding, and encouraging tech transfer, especially to small and medium-sized businesses.

▲ ***Representatives from ESG demonstrate the simulators they use to test the information technology systems that will be embedded in automobiles and aircraft.***

PHOTO BY DARREN JACKLIN

The American participants were impressed by the deliberateness of a fully worked-out system aimed at surrounding firms with everything they might need to innovate. And yet, German workshop attendees also reflected on the possible shortcomings of their system, which prompted a frank dialogue about the strengths and weaknesses of two contrasting, but highly successful, innovation systems. While the Americans were struck by the strong embrace of regional collaboration and the sophistication of government's engagement in technology development, the Germans remained envious of American-style business dynamism.

Along those lines, participants heard from American experts from Clemson University's International Center for Automotive Research (CU-ICAR) and TechShop, a national network of maker spaces that provides entrepreneurs access to tools, software, and workspace. Several university-based former ESG employees applauded American entrepreneurship and worried about the inertia of the highly procedural German system. Others perceived a weakness in Germany on the production of "radical new ideas" and worried about a lack of attention to start-ups and small companies, latter of which is a specific focus of the TechShop model. The encounter played out as a balanced weighing of two successful, but imperfect, national innovation systems with each having much to learn from the other.

III. GERMANY'S WORKFORCE TRAINING SYSTEM

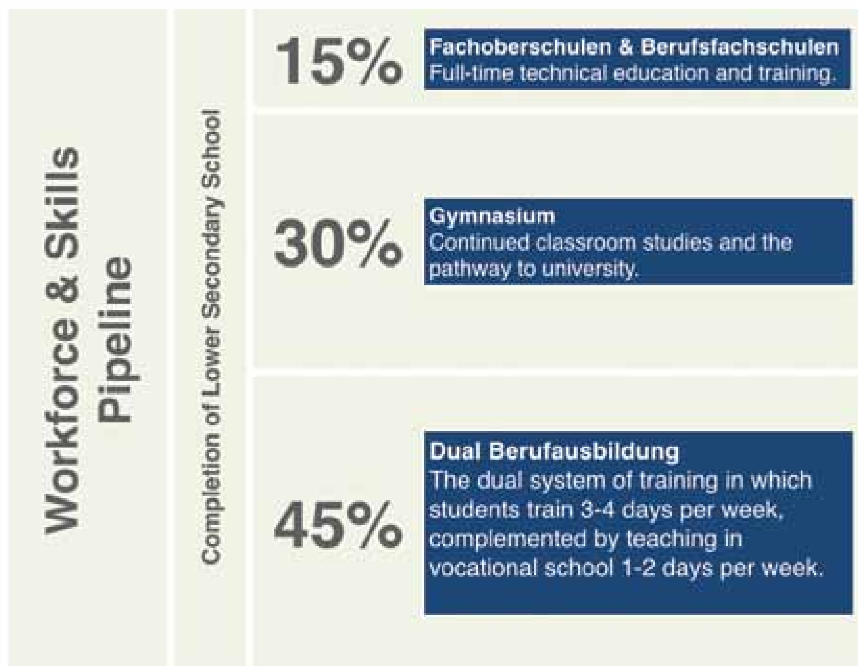
If innovation continues to be the key to raising living standards, human capital remains a critical determinant of innovation.[69] While the term innovation may invoke radical breakthroughs such as the internet or the iPhone, research suggests that most firm-level innovation is actually incremental in nature, and therefore relies on a broad swath of the workforce.[70] Manufacturing epitomizes this phenomenon: The complex, capital-intensive systems that increasingly define manufacturing demand qualified production workers who possess the practical knowledge, creativity and adaptability to implement and improve new processes and technologies.[71] And it is workers' ability to complement machines that increasingly determine their productivity, and therefore the wages they can command.[72]

THE DUAL SYSTEM: EDUCATION AND WORK

The German education and training system has been particularly adept at preparing its manufacturing workforce to complement new technology.[73] This preparation begins relatively early in the education system as compared to other countries. German students are tracked at an early age.[74] The school system closely follows the performance of primary school pupils to assess their ideal educational path. When students finish primary school (at the age of 10-12), parents, students, and educators together decide on one of three common lower secondary schools: general secondary school (***Hauptschule***), Intermediate School (***Realschule***), and Grammar School (***Gymnasium***).[75] Upon completion of lower secondary school three pathways to employment emerge—45 percent of students enter the dual system (***Dual Berufsausbildung***), 15 percent pursue full-time vocational education and training (***Fachoberschulen*** and ***Berufsfachschulen***), and 30 percent continue ***Gymnasium*** en route to university.[76]

The most common pathway to a job is the dual system, through which students obtain field-specific workplace skills in one of 349 occupations (as of 2013) that cover all aspects of the economy. Training occurs mainly through a two- to three-year apprenticeship at a firm, where students train three or four days a week. Students spend the remaining one or two days per week at a part-time vocational school (*Berufsschule*) where they receive more theoretical training. According to the most recent statistics, 1.46 million young people participated in apprenticeships in 2011. While this is still the dominant pathway to the labor force, participation in the dual system declined 3.2 percent between 2010 and 2011, as more young people pursued the university track.[77] Germany is actively promoting greater participation in university-based higher education. This emphasis has led to recent reforms that aim to ease the transition from the dual system to university, which according to an OECD review has not historically been a common pathway.[78]

Figure 2. Germany's Workforce and Skills Pipeline



Source: Brookings Institution with information from the Federal Institute for Vocational Education and Training (BIBB).

THE ROLE OF EMPLOYERS, GOVERNMENT, AND OTHER SOCIAL PARTNERS IN THE DUAL SYSTEM

From the very beginning of the journey from school to work, dual system participants establish close relationships with employers.[79] Companies sign contracts with young people under private law and provide them an hourly wage just below that of an entry-level worker. On-the-job training typically comprises two-thirds of the curriculum in the dual system and the contents of the curriculum as well as supervision are the responsibility of the hiring company, with active monitoring by the industrial chambers of commerce and state government to ensure training is in accordance with national occupational standards. Firms also contribute about two-thirds of the overall costs (approximately €5.6 billion in 2010) of the dual system through on-the-job training (states cover the remaining costs).[80] Twenty-two percent of German companies offered on-the-job training in 2011.[81]

Employers participate in the dual system for several reasons. Evidence suggests that German manufacturers do not recoup the cost of training apprentices during the apprenticeship.[82] Rather, they are viewed as a human capital investment that will pay off as apprentices become more skilled full-time workers upon completion of their training.[83] Skills investments are justified because access to qualified labor provides firms a productivity advantage over their competitors, given that many technical skills remain relatively scarce.[84] Additionally, solid worker protections from the country's powerful labor unions make firing workers more difficult than in countries like the United States. Apprenticeships allow German manufacturers to evaluate young workers before hiring them full-time, and significant investments in skills are more attractive to companies when they know workers will be in their factories long-term.

Manufacturers in Germany are better able to participate in the education and workforce system because they are organized by a network of supporting chambers of commerce, government, and labor organizations.

The dual system relies heavily on the national network of 80 regional chambers of industry and commerce (IHK), which employers are required by law to join and serve two critical functions. First, the IHKs are the organizing voice for industry in the workforce system. Instead of an individual employer having to spend the time and resources to establish a specific, one-off collaboration with a vocational school, it can engage the system under the umbrella of the IHKs. Further, IHKs represent firms during training regulation negotiations with the federal government, state government, and trade unions. Second, the IHKs provide institutional support to ensure that firms comply with the standards of the Vocational Training Act of 1969 (updated in 2005). IHK experts assist companies with vocational training, register the training contracts, help conceive occupational examinations, examine trainees and instructors, and withdraw training permission in case companies violate training standards.[85] There is no equivalent American organization that provides the scope and depth of firm-level support provided by the IHKs in the German workforce system.

On the public sector side, the federal government, through the Federal Ministry of Education and Research (BMBF), the Federal Ministry of Economics and Technology (BMWi), and the Federal Employment Agency (BA), supervises the implementation of the general guidelines established in the Vocational Training Act. The nationally-organized advisory committee for the Federal Institute for Vocational Education and Training (BIBB) facilitates dialogue between the private sector, state government, unions, and local officials to establish occupational credentials.[86]

The Länder (state) governments, represented by their ministries of education and economic affairs, are responsible for vocational schools, overseeing the IHKs, and promoting cooperation between the school-based and work-based aspects of the dual system. State governments contribute about one-third of the costs of the dual system (approximately €3.1 billion).[87] Individual state governments are advised by Länder vocational training committees that include representatives from relevant state ministries, employer associations and chambers, and workers. And the Conference of State Ministers of Education (KMK) decides on common approaches and national recognition of the types of school, curriculum standards, and qualifications.[88]

Workers, typically via the country's powerful labor unions, participate in various stages of the dual system—advising state and national vocational education and training committees, negotiating occupational credentials, and sitting on works councils.[89]

THE ROLE OF OCCUPATIONAL CERTIFICATIONS IN THE DUAL SYSTEM

The high degree of collaboration between government, labor, and employees reflects itself in the dual system's establishment of nationally-defined, industry-recognized occupational certifications, around which the social partners and government organize training. Upon completing an apprenticeship or full-time vocational degree, German students are accredited by the BIBB, based on their performance on examinations administered by the country's chambers of commerce in areas such as industry, health, agriculture, and commerce. Approximately 60 percent of Germans receive a relevant occupational certification by the age of 20, either through the dual system or a full-time vocational school.[90]

As of 2013 there were 349 different federally-recognized certifications, which are quite stringent by international standards and remain a requirement for employability.[91] For certifications to have lasting significance they must be continuously updated and new occupations must be added to keep pace with technological and economic change.[92] The process of upgrading training requirements and certifications begins with industry. Employers notify their chamber of commerce, who then pass along the request to the BIBB, where experts study it and, if deemed necessary, upgrade the training regulations. BIBB decisions receive input from an advisory committee with members from the private sector, state government, unions, and municipalities. For occupational upgrades, the entire process takes about a year while a new occupation definition typically takes two years.[93] Almost one-third of existing occupations have been created in the last 15 years to respond to the rapid technological change occurring in many industries.[94]

A national credentialing system contributes to labor market transparency and certainty. Credentials jointly determined by employers and educators provide certainty for: 1) students, who have reasonable confidence that their education investment will be recognized and rewarded by employers; 2) educators, who better ensure that the education they are providing is economically relevant; and 3) employers, who more clearly understand how prospective employees' education, competencies, and skills match the needs of their open positions. Credentials also ensure portability across states: a company in Bavaria operates under the same certification system as a company in Baden-Württemberg. This regime differs markedly from the highly decentralized, opaque system of occupational credentialing in the United States.

Centralized certifications are not without drawbacks, however. They may limit labor market flexibility: The barrier to entry for occupations can be unnecessarily high for professions that do not actually need formal training, or transitioning to a new occupation may be overly difficult because workers must restart the training process to gain a new certification. In response to these critiques, policies have been put in place that count qualifications obtained through the dual system or full-time vocational education towards other occupational credentialing or the further pursuit of higher education.[95]

The main takeaway: The German education and training system significantly aids innovation within the manufacturing sector.[96] First, the system endows manufacturing workers with general skills in different clusters of industries, providing a basic foundation so they can accrue very specialized on-the-job skills.[97] Second, the occupational profiles take into consideration best practices in human capital development, with a strong emphasis on active learning and adaptability. This approach favors early-career apprenticeships in addition to lifelong training, often supported by companies, so technical workers can improve production processes and effectively implement innovations along the value chain as technologies change.[98] And third, the entire training system nimbly responds to industrial and occupational changes due to close cooperation between companies, industrial chambers, research institutions, and government agencies.[99] Drawing on this collaborative system to train their workers has helped Germany's world-renowned ***Mittelstand*** keep their products at the cutting edge of global markets.[100]

STUDY TOUR: OBSERVING THE DUAL SYSTEM ON THE FACTORY FLOOR AT SIEMENS AND SEIDENADER[101]

The Global Cities Initiative delegation visited two Bavarian companies—Siemens and Seidenader—to understand the German approach to work-based education and training from the perspective of a major multinational firm and a *Mittelstand* company, respectively. After touring Siemens' Nuremberg factory floor, participants heard from executive Jürgen Siebel about why the company invests significantly in its apprenticeship program. For starters, youth unemployment rates are still unacceptably high in most of the world—14 percent in the United States and well above 25 percent in parts of Southern Europe—a threat to both economic competitiveness and societal stability. He argued that a skilled and flexible labor market is critical to sustaining a full and lasting recovery, preserving a strong industrial base, and therefore enhancing Siemens' profitability. Achieving these outcomes requires a focus on what Siebel called a young person's employability, the set of technical competencies and workplace norms required for success in any career.

An apprentice at Siemens demonstrates his final project—model smart grid—to Amy Liu of Brookings and Karin Norington-Reaves of the Chicago-Cook Workforce Partnership.

PHOTO BY DARREN JACKLIN

The U.S. delegation heard firsthand from more than a dozen Siemens apprentices in the Nuremberg training facility. Here, young people from the ages of 16 to 21 learn everything from basic production (e.g. milling, drilling, filing, etc.) to more advanced skills such as mechatronics and electrical engineering. They are pursuing a range of educational credentials alongside work, from the dual system apprenticeship to community college and university degrees. Siemens hires the vast majority of its apprentices, 2,000 in Germany alone, into full-time employment after they complete their apprenticeship. American participants remarked that beyond the first-class technical skills apprentices displayed, these young people's soft skills—their ability to work in teams, their confident presentation, and their full command of English—were perhaps even more impressive. Siemens, one of Germany's largest and most prestigious companies, has the luxury of selecting the most talented apprentices from a highly competitive application process.

The following day the delegation visited Seidenader, a 400-employee manufacturer of visual inspection machines for pharmaceutical products located just outside Munich. Even though it is much smaller than Siemens, Seidenader maintains a similarly robust apprenticeship program. Each year, the firm's leadership visits local schools, provides weeklong internships to high school students, and selects apprentice candidates based on interest and aptitude. The firm's strong recent growth has allowed it to bring in dozens of apprentices a year, training them for two to three years in technical and commercial occupations while they also attend school. Unlike at Siemens, where apprentices are educated in a separate training facility, Seidenader's apprentices work right alongside other employees on the production line, in machine installation and maintenance, and in sales and marketing. Management reports that the firm has hired about 90 percent of apprentices upon their completion of the program. Two-thirds of Seidenader's workers end up pursuing more education with support from the company—to gain new skills with hopes of a higher income and more responsibility at the factory.

Note: Siemens AG provides financial support to Brookings

IV. GERMAN ELEMENTS OF SUCCESS FOR U.S. SKILLS AND INNOVATION STRATEGIES

In both skills training and technological innovation, U.S. policies to support manufacturing have not matched the sector's evolution from one dominated by massive, vertically-integrated companies to a more distributed mix of small, medium, and large firms. Research and development, particularly applied research, and training are underprovided in the market as individual firms are fearful they will not recoup their full investment. Each suffers from a market failure which business, civic, and policy leaders must together address to curb the country's long-term decline in manufacturing.

Meanwhile, Germany's public-private collaborations around technology and its dual model for vocational education are widely considered global best practices. But can they be transferred to the United States?

Notwithstanding the two countries' similarly devolved federalist systems, there are important differences that may impede full adoption. First, government plays a more significant role in shaping the economy in Germany than in the United States. Government spending as a share of GDP in Germany (45.3 percent) exceeds that of the United States (41.7 percent) and the federal government has historically intervened more in businesses and labor markets.[102]

Second, the relationship between business and labor differs markedly across the two countries. Firm membership in industrial chambers of commerce is mandatory in Germany. German law requires workers to have a seat on a company-level works council to bargain with management on changes to company practices.[103] Union coverage rates are also dramatically higher: Approximately 61 percent of eligible German workers were covered by a collective bargaining agreement in 2011 versus 13 percent of American workers.[104]

Third, both the vocational education system and collaborations on technology development have a long history in Germany, with the former rooted in the country's medieval guilds, raising questions about whether they can be quickly adopted by other countries.[105]

These political and cultural differences suggest that the German model cannot and should not be imported whole cloth. Rather its most successful elements can be drawn out, documented, and then tailored to our unique political economy and federalist system. Three key takeaways—regional collaboration between public, private, and civic actors; targeted institutional intermediaries that address market and coordination failures; and incentive-based investments to support SMEs—should guide U.S. practitioners and policymakers seeking to adapt German skills and innovation best practices to support manufacturing. As with most policy advancements in the United States, especially given continued paralysis in Washington, early adoption will occur in the country's cities, regions, and states. Indeed, several U.S. regions and states have already adopted at least one of these three "elements of success" to guide their workforce and innovation strategies.

REGIONAL COLLABORATION

Germany's regions display distinct levels of collaboration between government, educational institutions, employer associations, and firms to support the skills and technology innovation demands of key manufacturing industries. Similarly impressive levels of coordination are occurring across leading U.S. regions:

- In **San Diego, CA** a dense network of universities, research institutions, economic development organizations, talented workers, and innovative firms have collaborated for decades to build and nurture its world-beating clusters in life sciences and information technology (IT).

INNOVATION | NETWORKS, CLUSTERS, AND TALENT FURTHER INNOVATION IN SAN DIEGO

San Diego exemplifies how a metro area can leverage its regional resources to foster innovation and promote the creation of high-tech clusters. Over the past 40 years, San Diego has transformed from a defense, real estate development, and tourism dependent economy to a world-leading hub of biotechnology and information and communication technology companies. Its economic transformation can be explained by three critical elements that helped the metro area leverage its regional resources effectively: a dense network of institutions and universities that perform cutting edge research; the existence of organizations that aid the creation of technology-oriented companies; and a steady supply of highly qualified workers to foster innovation.[106]

First, a dense network of research institutions, including six universities and more than 80 research institutes, provide the scientific knowledge and resources to San Diego companies to develop new products. The San Diego innovation network promotes joint research projects that diffuse relevant knowledge across firms, a critical process in the formation of high-tech clusters, and fosters the development of a network of entrepreneurs and researchers.[107]

Second, San Diego's manufacturers have also benefited from cluster-focused organizations like CONNECT. Focused on life science and technology products, CONNECT helps organize entrepreneurs, scientists, business services providers, and venture capitalists. Firms are able to tap into the ideas, managerial expertise, capital, and business services necessary for their early growth. CONNECT's $3.7 million budget is sustained through membership fees and has helped in the creation of more than 3,000 companies in the region.[108]

Third, a constant supply of qualified workers has allowed San Diego to sustain and expand innovative products. Universities such as UC-San Diego, the University of San Diego, and San Diego State University, and research institutions like the Salk Institute for Biological Studies and the Scripps Research Institute, are the main suppliers of technically trained workers. These researchers and the industry clusters to which they belong have higher average wages compared to other industries both in San Diego and nationally, and have registered higher growth in wages than other industries.[109]

Finally, San Diego has developed into a high-tech cluster by making effective use of local, state, and federal resources. State and federal funding to universities and other research institutions was critical for the development of the underlying science behind many of the firms located in San Diego. Furthermore, the existence of a research network is a necessary condition for the emergence of innovation but not a sufficient one. The active involvement of different stakeholders through organizations like CONNECT and the provision of the right incentives to promote joint research and collaborative networks are equally important.

BEST PRACTICES: CONNECT, NorTech, SEMATECH

➤ Led by Toyota, manufacturers in the **Louisville-Lexington region** have created an industry-led consortium in partnership with a local community college to strengthen the region's supply of young technical workers.

SKILLS | KENTUCKY FAME BUILDS REGIONAL TALENT SUPPLY

Kentucky's automotive industry, the state's largest manufacturing industry, employs 65,000 workers at over 400 facilities.[110] None hosts more jobs than Toyota's Georgetown plant—where 7,000 workers support the manufacture of the Camry, Avalon and Venza models—the company's largest outside Japan.[111]

Yet beginning in 2009, Toyota executives began to register concern that the region's workforce would not be able to replace the pending wave of front-line worker retirements. In response, the company partnered with the Bluegrass Community and Technical College (BCTC) to create the Advanced Manufacturing Technician (AMT) program—a multi-disciplinary degree focused on electricity, fluid power, mechanics, and fabrication—to strengthen the supply of young manufacturing workers in the Lexington region.[112] Since then, the AMT program has expanded to upwards of 15 additional companies and now operates under a regional consortium called the Kentucky Federation of Advanced Manufacturing Education (KY FAME).

In many ways the AMT program resembles the German approach to dual-track training. Participating companies recruit from a pool of high school students that must meet a stringent set of requirements to be considered: 1) graduated from a Project Lead The Way high school (Project Lead The Way is a K-12 STEM program operating in 6,500 elementary, middle, and high schools nationwide); 2) scored at least a 25 on their ACT; and 3) maintained at least a 3.0 GPA.[113] Once sponsored by a company, AMT trainees undertake a two-year apprenticeship through which they attend classes at BCTC two days a week and earn a wage between $12 and $16 working for the sponsor company for the remaining three days.[114] Most students complete the program debt-free.[115]

The region's educational institutions engage closely with employers. BCTC has a campus on Toyota's grounds so that selected students can get first-hand training with robots, computers and other equipment. In the fall of 2014, new construction began on a $24 million advanced manufacturing training center associated with BCTC.[117] And four-year programs at Northwood University and the University of Kentucky are available for those students seeking an engineering degree upon completion of AMT.

KY FAME is a unique example of regional collaboration because it is entirely employer-generated. After developing AMT, Toyota helped organize other regional manufacturers with similar talent needs, including those in their supply chain, growing the program from four companies sponsoring 15 students in 2013 to 15 companies sponsoring 50 students by the fall of 2014. In 2013 Toyota's AMT was recognized as the nation's top Career Pathway program by the National Career Pathways Network and its early success is now being replicated in other parts of the state, including as a key element of Louisville-Lexington's Bluegrass Economic Advancement Movement (BEAM) manufacturing strategy. A central challenge, however, is resources. Currently, KY FAME has no devoted staff, but rather relies on staff at participating companies to fundraise, market, and organize the collaborative. Private and public leaders alike recognize the need to hire full-time staff and are exploring different models, from state and federal grants to company membership dues, to finance KY FAME's next phase.

BEST PRACTICES: KY FAME, Centers of Excellence, Partners for a Competitive Workforce

TARGETED INSTITUTIONAL INTERMEDIARIES

A second German element of success is its institutions, which in turn support regional collaboration. German manufacturers receive support from tailored intermediaries designed to correct for the market's under-provision of pre-competitive research (Fraunhofer Institutes) and job training (regional chambers of commerce). Similar institutions, albeit at a smaller scale, provide similar benefits in U.S. regions:

- In **Detroit, MI** a reinvigorated manufacturing base draws on the institutional knowledge, capabilities, and space from one of Fraunhofer USA's seven American locations to help cultivate a new specialization in battery technology.

INNOVATION | FRAUNHOFER USA HELPS POWER DETROIT'S BATTERY INDUSTRY

As Detroit's manufacturing base emerges from the Great Recession, the region is providing resources to companies to engage in research and development and drawing on a deep network of research institutions to cultivate new specializations in advanced technologies. Detroit's efforts to become an innovation hub are exemplified by Inmatech, a startup manufacturing company that fabricates efficient, low cost lead-acid batteries that are used in the automotive industry, electrical grids, and other defense-related systems.[120]

Founded in 2010, Inmatech's emergence is the product of many institutions and actors. The technology behind its prototype is the result of basic research conducted by Levi Thompson, professor of chemical engineering at the University of Michigan and director of the school's Hydrogen Energy Technology Laboratory, which is part of a broader research effort involving Wayne University and Michigan State University to promote technologies that impact advanced manufacturing.[121]

In addition to their collaboration with the University of Michigan, Inmatech has worked closely with the Fraunhofer Center for Coatings and Laser Applications (CCL).[122] Their joint work allowed Inmatech to develop a supercapacitor, a class of electrochemical energy-storage device that complements batteries for uninterruptible power supply applications. This component was necessary for their final prototype, and was successfully developed thanks to the ample technical and commercial expertise of researchers at Fraunhofer.

Finally, local and federal governments as well as local stakeholders provided critical support to Inmatech. The company's battery prototype was funded by $610,000 in small-business innovation grants from the National Science Foundation.[123] Inmatech has also received funds from local and regional grants and awards, including the Lakes Entrepreneur's Quest and the Michigan Clean Energy Prize.

Inmatech is now poised to impact multiple industries, like electricity generation, defense, and aeronautics, thanks to the ecosystem that facilitated the development of its technology.

BEST PRACTICES: **Fraunhofer USA**, **EWI**, **CU-ICAR**, **Commonwealth Center for Advanced Manufacturing**, **TechShop**

➤ A sector-based workforce intermediary in **Southeast Michigan** has effectively overcome significant coordination challenges to create an advanced technician training program in conjunction with area manufacturers and community colleges.

SKILLS | MICHIGAN ADVANCED TECHNICIAN TRAINING PROGRAM (MAT²)

Detroit's post-recession recovery has been one of the nation's strongest, ranking fourth among the nation's 100 largest metropolitan areas, bolstered by a 29 percent increase in manufacturing jobs.[124] Yet as the region's manufacturers increased production, they discovered an insufficient pipeline of workers with competencies in mechatronics, a design process that requires knowledge of mechanical engineering, electronics, and computer programming. It was at about this same time that Michigan Governor Rick Snyder participated in a trade mission to Germany, where he became convinced that a statewide initiative resembling the dual system could help Michigan's manufacturing skills shortage.[125]

Upon returning from his trip, Governor Snyder asked the Michigan Economic Development Corporation (MEDC) to help overcome the collective action problems that so often plague pilot workforce development initiatives. Community colleges needed to be convinced that they would enroll at least 15 students to make a capital-intensive mechatronics program cost-effective. Employers needed to be convinced that the program would be worth the approximately $20,000 annual cost to cover apprentices' tuition and wages. And students and parents, with the job losses of the Great Recession fresh in their minds, needed to be convinced that a manufacturing training program offered a viable pathway to well-paid career with advancement opportunities.

In 2013, MEDC launched the Michigan Advanced Technician Training Program, or MAT², along with Henry Ford Community College and Oakland Community College and 11 Southeast Michigan manufacturers. The first cohort contained 31 students and focused only on mechatronics, but by September 2014 MAT² had expanded to include 29 employers, 98 students, four community colleges and now offers additional programs in Information Technology and Technical Product Design.[126] Each program costs about $300,000 to launch and MAT² maintains an annual budget of $1 million, which is supported by the state of Michigan.[127]

MEDC, a quasi-public agency, has been the coordinating body during the program's ramp up, with support from an advisory committee that includes representatives from industry, community colleges, the Department of Labor, and the German-American Chamber of Commerce.[128] German and American manufacturing firms work with the participating community colleges to design the curriculum and core competencies, cover their trainees' tuition, and pay them between $9 and $12 per hour over the course of the program.[129] Graduating high school seniors that prefer an alternative route to a four-year university can gain theory, practice, and work experience over the course of the three-year program. MAT² markets the program at college and career fairs and Metro Detroit school districts.[130] Successful graduates of the three-year training program receive an associate's degree, a nationally-recognized credential from the Department of Labor and/or a national-recognized credential by the German IHK, and a company certificate (when applicable). Most importantly, they have an entry-level technician job waiting for them.[131]

BEST PRACTICES: MAT², Apprenticeship 2000, Wisconsin Regional Training Partnership

INVESTMENT

Finally, manufacturers in Germany receive a diversity of public investments to incentivize companies, particularly SMEs, to invest in technology and train workers. Several forward-looking U.S. states are making these types of strategic investments:

- While most funding for basic and applied research occurs at the federal level, states are also supporting companies with targeted investments. In **Pennsylvania**, Ben Franklin Technology Partners spurs economic growth by investing in technology commercialization.

INNOVATION | INVESTMENTS IN INNOVATION: BEN FRANKLIN TECHNOLOGY PARTNERS

Three decades ago Pennsylvania's political leadership founded the Ben Franklin Technology Partners (BFTP) to catalyze technology-led economic growth. Through its four regional headquarters, BFTP provides companies with capital, technical assistance, and connections to a broad network of firms, universities, and experts.

BFTP makes direct investments to both start-ups and established companies seeking to commercialize new technologies. Through a rigorous vetting process, BFTP has made over 3,500 investments in Pennsylvania companies since its founding in 1983. Often BFTP has been one of the first institutional investors in a company, helping solidify commercialization efforts and spurring additional capital injections from other investors.[132] For instance, BFTP seeded the first capital investment to a young researcher from Johns Hopkins Medical School to commercialize his research on cancer and infectious disease treatments. That researcher went on to found Morphotek, which today employs 200 workers and is one of the leading life sciences companies in Pennsylvania.[133]

BFTP's experts also deliver technical assistance. The organization's experts help young companies with product development, marketing, fundraising, accounting, operations, and human resources. This aspect of BFTP's work helps companies chart a growth path that takes them from their initial idea to full commercialization.[134]

Finally, and perhaps most importantly, BFTP serves as the hub of a deep institutional network that can be tapped to support companies. This network stretches across the investor community, universities and research labs, state and regional economic development organizations, business incubators, and other entrepreneurs. Since 1987, East Penn Manufacturing, one of the world's largest battery manufacturers, has drawn on BFTP's networking capabilities to partner with Lehigh University, Enterprise Systems Partners, Penn College of Technology's Plastics Innovation and Resource Center, and Northampton Community College's Emerging Technology Applications Center.[135]

Together, these services have yielded real economic benefit. An evaluation of BFTP by Pennsylvania Economy League and KLIOS Consulting estimated that since 1989 BFTP has contributed over $23 billion to the state economy, helped create 51,000 jobs in its firms, and generated a 3.6-to-1 return on investment in terms of state tax revenue.[136] Strong economic outcomes from its relatively modest budget (around $14 million as of 2011) continue to position BFTP as a leading state-level best practice.[137]

BEST PRACTICES: **Ben Franklin Technology Partners**, **CTNext**, **Advanced Industry Accelerator Program**

- States are taking the lead in making investments to connect young people with employment opportunities. **South Carolina** has utilized an employer tax credit to create one of the country's largest and fastest growing apprenticeship programs.

SKILLS | APPRENTICESHIP CAROLINA: CREATING NEW PATHWAYS TO MANUFACTURING EMPLOYMENT

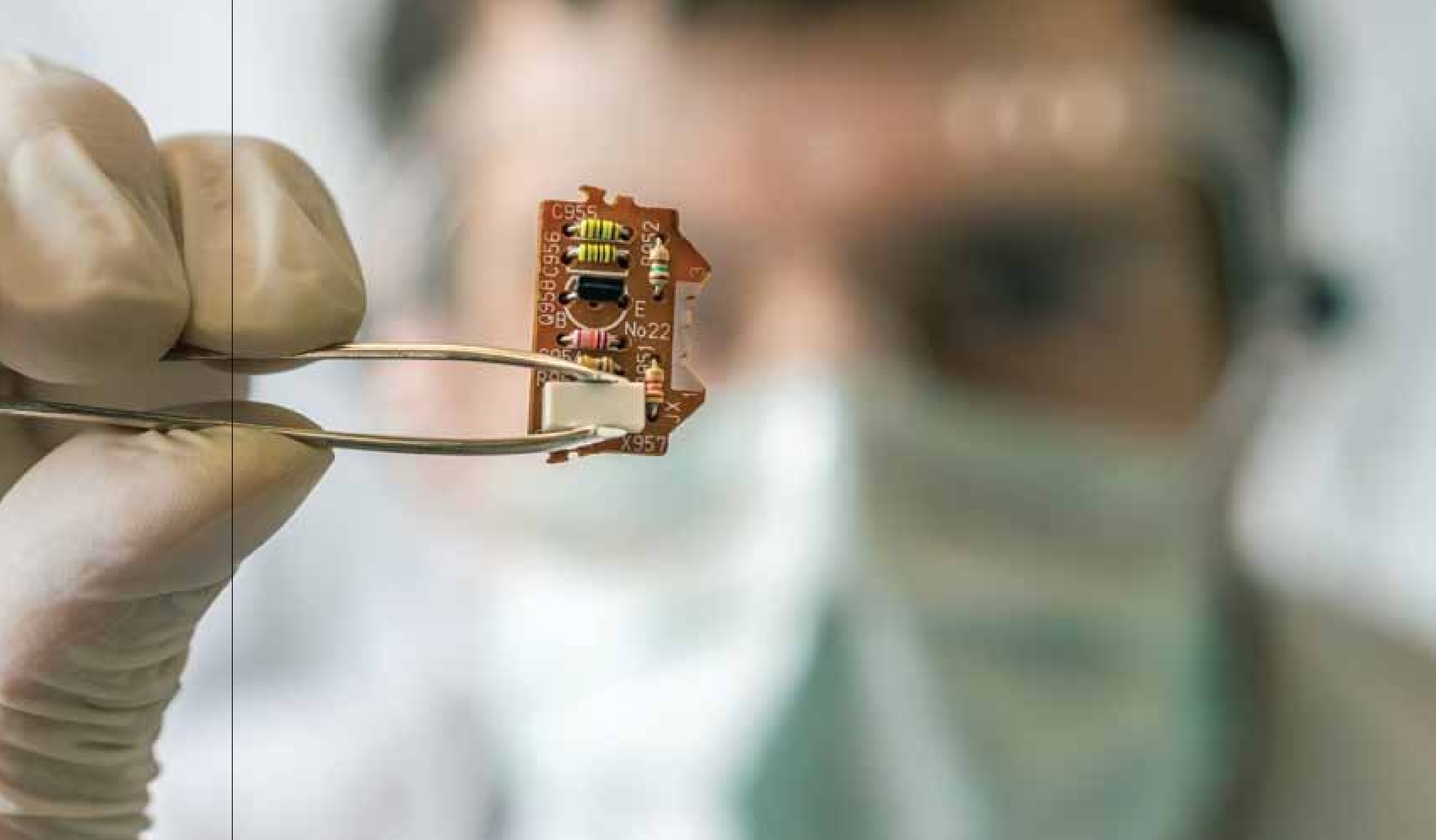
South Carolina has long been a destination for German companies—from BMW to ZF to Bosch. The state has now become an early adopter of incentivizing apprenticeships through its statewide program, Apprenticeship Carolina.

Apprenticeship Carolina operates in 46 counties across South Carolina to expand junior and adult apprenticeship programs in manufacturing, technology, healthcare, and other industries. Initiated under a special grant from the state legislature and housed within the South Carolina Technical College system, Apprenticeship Carolina provides companies with free apprenticeship consultants to guide them through the registered apprenticeship development process, from initial information to full recognition in the national Registered Apprenticeship System.[138] Consultants identify occupational training gaps, solicit proper supervisors for apprentices, link to providers for related technical instruction (often at one of the state's 16 technical colleges), and recruit a supervisor to maintain training standards.[139] The program costs about $1 million a year, which is covered through state funding and includes an annual employer tax credit of $1,000 per apprentice.[140]

The apprenticeship typically consists of two main components: 1) on-the-job training at the workplace; and 2) a job-related technical instruction at a local community or technical college. As the apprentice's skills progress, so does their pay through a set formula. It is also a way for an employer, who sets the wage levels, to offset costs when investing in employees who are not immediately fully productive and to retain employers when investing in their training.[141] For instance, the BMW Scholars program offers full-time students at three local community colleges the opportunity to work up to 20 hours per week at BMW's Spartanburg auto plant while they complete their two-year degree.[142]

Apprenticeship Carolina has achieved remarkable growth. Begun in 2007 with just 777 trainees and 90 companies, it has since served over 10,000 students and more than 650 companies.[143] Yet the program is not without its challenges. First, an underlying concern for participating companies is that other companies that do not invest in the apprenticeship program can still profit by poaching or hiring workers who have been trained by other companies. Second, the program can still improve collaboration between businesses and educational institutions and better connect apprenticeship skills and credentials to the university credit system. Nevertheless, Apprenticeship Carolina serves as an attractive state-level model to expand pathways to manufacturing.

BEST PRACTICES: **Apprenticeship Carolina**, **Connecticut Department of Labor**, **Tennessee Promise**



V. CONCLUSION

Germany's leading manufacturing regions can serve as exemplars for U.S. leaders seeking to build and sustain their own manufacturing sectors. As the Global Cities Initiative investigated in Munich and Nuremberg, three elements of success—regional collaboration between public, private, and civic actors; targeted institutional intermediaries that address market and coordination failures; and incentive-based investments to support SMEs—should guide U.S. practitioners and policymakers seeking to adapt German skills and innovation best practices to support manufacturing here at home.

U.S. jurisdictions as diverse as Detroit, San Diego, Pennsylvania, and South Carolina are adopting these methods because they recognize manufacturing remains an important contributor to growth, job creation, trade, and innovation. And while Germany maintains a different culture and political economy than the United States, the country's best practices represent powerful tools for American efforts to strengthen manufacturing through skills and innovation. ■

ENDNOTES

1. Marc Levinson, "U.S. Manufacturing in International Perspective" (Washington: Congressional Research Service, 2013).

2. Brookings analysis of Bureau of Economic Analysis data and Bureau of Labor statistics data.

3. Harold L. Sirkin, Justin Rose, and Michael Zinser, *The U.S. Manufacturing Renaissance: How Shifting Global Economics Are Creating an American Comeback* (Philadelphia: Knowledge@ Wharton, 2012).

4. Gary Pisano and Willy Shih, *Producing Prosperity: Why America Needs a Manufacturing Renaissance* (Boston: Harvard Business Review Press, 2012). Mark Muro, "Reshoring: Strong Regions Will Determine Where, How," *The Avenue*, October 2, 2014 (www.brookings.edu/blogs/the-avenue/posts/2014/10/02-reshoring-strong-regions-muro).

5. Suzanne Berger, *Making in America: From Innovation to Market*, (Boston: MIT, 2013).

6. Pisano and Shih, Producing Prosperity, 2012. Mark Muro and others, "America's Advanced Industries: What They Are, Where They Are, and Why They Matter" (Washington: Brookings Institution, 2015).

7. Richard Freeman, "The Great Doubling: The Challenge of the New Global Labor Market," Working Paper (2006). Gary Gereffi and others, "The Governance of Global Value Chains," *Review of International Political Economy* 12 (1) (2005): 78–104.

8. Gerald F. Davis, *Managed by the Markets: How Financed Re-Shaped America*, (New York: Oxford University, 2009). Berger, *Making in America*, 2013. Stacey Jarrett Wagner, "Creating a Skilled Manufacturing Workforce." In Richard McCormack, ed., *ReMaking America* (Washington: The Alliance for American Manufacturing, 2013).

9. Samuel E. Henly and Juan M. Sanchez, "The U.S. Establishment-Size Distribution: Secular Changes and Sectoral Decomposition," *Economic Quarterly*, 95 (4) (2009): 419–454.

10. Berger, *Making in America*, 2013.

11. Ibid.

12. Pisano and Shih, *Producing Prosperity*, 2012.

13. Gregory Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies." *Journal of Technology Transfer* 35 (3) (2010): 283–333. Pisano and Shih, *Producing Prosperity*, 2012.

14. Muro and others, "America's Advanced Industries." Sridhar Kota, "The Role of Innovation." In Richard McCormack, ed., *ReMaking America*, (Washington: The Alliance for American Manufacturing, 2013). Pisano and Shih, *Producing Prosperity*, 2012. Tassey, "Rationales and mechanisms" for revitalizing U.S. manufacturing R&D strategies,"

15. Pisano and Shih, *Producing Prosperity*, 2012.

16. Ibid.

17. Muro and others, "America's Advanced Industries." Kota, "The Role of Innovation." Pisano and Shih, *Producing Prosperity*, 2012. Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies."

18. "What is pre-competitive research?" available at: www.ccmx.ch/industry/how-to-participate/what-is-pre-competitive-research/ (October 2014).

19. Pisano and Shih, *Producing Prosperity*, 2012. As a result the benefits of a radical innovation are limited to the early adoption of a new technology when the entrepreneur's enjoy a natural monopoly of their product. Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies."

20. Brookings analysis of data from the U.S. Census Bureau's Foreign Trade Division (NAICS: 334413).

21. Berger, *Making in America*, 2013. Wagner, "Creating a Skilled Manufacturing Workforce."

22. Berger, *Making in America*, 2013.

23. "Skills and Industry: A New American Model" available at: www.brookings.edu/~/media/events/2014/5/22%20 metro/20140522_skills_industry_transcript.pdf (October 2014).

24. Jonathan Rothwell, "Still Searching: Job Vacancies and STEM Skills" (Washington: Brookings Institution, 2014).

25. James Manyika and others, "Manufacturing the Future: The Next Era of Global Growth and Innovation," (San Francisco: McKinsey Global Institute, 2012).

26. Andrew Weaver and Paul Osterman, "The New Skill Production System: Policy Challenges and Solutions in Manufacturing Labor Markets." In Richard M. Locke and Rachel L. Wellhausen, eds., *Production in the Innovation Economy*, (Cambridge: The MIT Press, 2014).

27. "Skills and Industry: A New American Model." "Advanced Manufacturing Partnership 2.0" available at: www.manufacturing.gov/amp.html (October 2014). "Employment and Unemployment Among Youth Summary," available at: www.bls.gov/news.release/youth.nr0.htm (October 2014).

28. Brookings analysis of OECD data. Organization for Economic Co-Operation and Development (OECD), Short-Term Labour Market Statistics, "Employment by industry," available at stats.oecd.org/index.aspx?queryid=38899 (July 2014).

29. Brookings analysis of German Federal Statistical Office (Destatis) data.

30. Brookings analysis of United Nations Conference on Trade and Development (UNCTAD) data.

31. Brookings analysis of World Bank data.

32. Brookings analysis of OECD data. Organization for Economic Co-ordination and Development, Analytical Business Enterprise Research and Development (ANBERD) Dataset for 2012, available at: stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4 (2014).

33. Brookings analysis of OECD data.

34. Deutsche Statisches Bundesamt, "Berufliche Bildung statistiks für 2012," available at: www.destatis.de/DE/ZahlenFakten/GesellschaftStaat/BildungForschungKultur/BeruflicheBildung/Tabellen/AzubiAusbildungsbereich.html#Link (October 2014).

35. Bureau of Labor Statistics, "Table 1. Manufacturing (ISIC C, NAICS 31-33), Hourly compensation costs, U.S. Dollars, 2008-2012," available at: www.bls.gov/fls/ichccindustry.htm#C (July 2014).

36. Berger, *Making in America*, 2013.

37. George Washington Institute of Public Policy and RW Ventures, LLC, "Implementing Regionalism: Connecting Emerging Theory and Practice to Inform Economic Development" (Washington: George Washington University, 2011). Paul Romer, "The Origins of Endogenous Growth," *Journal of Economic Perspectives* 8 (1) (1994): 3-22; Paul Romer, "Endogenous Technological Change," *Journal of Political Economy* 98 (5) (1990): S71-102; Charles I. Jones, "Sources of U.S. Economic Growth in a World of Ideas." *American Economic Review* 92 (1) (2002): 220-239.

38. Mark Boroush, "NSF Introduces New Statistics on Business Innovation," NSF 11-300 (Arlington, VA: National Science Foundation, 2010)

39. Muro and others, "America's Advanced Industries."

40. David Soskice, "German Technology Policy, Innovation, and National Institutional Frameworks." Discussion paper No. FS I 96-319, (Berlin: Social Science Research Center, 1996).

41. "Research" available at: www.helmholtz.de/en/research/ (January 2014).

42. "Research News, Materials and Technology" available at www.mpg.de/research_news?filter_order=LT&research_topic=MT (January 2014). Max Planck Institutes had a close relationship with the industrial sector in the provision of applied research. However, due to their involvement in the war efforts of the Nazi regime, after the Second World War their role was limited to pure academic research. For more, see Diego Comin, Gunnar Trumbull & Kerry Yang, "Fraunhofer: Innovation in Germany" (Cambridge: Harvard Business School, 2011).

43. Knut Blind and Hariolf Grupp, "Interdependencies between science and technology infrastructure and innovation activities in German regions: empirical findings and policy consequences," *Research Policy* 28 (5) (1999): 451–468.

44. Robert Kaiser and Heiko Prange, "The reconfiguration of National Innovation Systems—the example of German biotechnology," *Research Policy* 33 (3) (2004): 395–408.

45. Fraunhofer Society, "Fraunhofer Jahresbericht 2013: Leben in der Digital Welt" (2014).

46. Comin and others, "Fraunhofer."

47. "What does Fraunhofer do?" available at: www.fraunhofer.de/en/quick-links/companies/what-does-Fraunhofer-do.html (January 2014).

48. Comin and others, "Fraunhofer." Stephen Ezell & Robert Atkinson, "International Benchmarking of Countries' Policies and Programs Supporting SME Manufacturers" (Washington: The Information Technology & Innovation Foundation, 2013).

49. Kathy Bergen, "A Model for Innovation." *The Chicago Tribune*, March 30, 2014.

50. Comin and others, "Fraunhofer."

51. Access to infrastructure for the development of new technologies has been found as one of the most significant reasons why SMEs engage in cooperative R&D activities with other firms and research institutions. Uwe Canter, Holger Graft and Susanne Hinzmann, "Policy Induced Innovation Networks: the case of the German 'Leading-Edge Cluster Competition.'" In Thomas Scherngell, ed., *The Geography of Networks and R&D Collaborations* (Heidelberg: Springer Link, 2013). Ezell and Atkinson, "International Benchmarking."

52. For example every Fraunhofer Institute is led by two co-chairs, one representing the private sector, and other representing the research community. Additionally, Fraunhofer offers five-year contracts to researchers from the Max Planck Institutes who want to apply some of their basic technology into some of Fraunhofer project. Comin and others, "Fraunhofer."

53. Marian Beise and Harald Stahl, "Public research and industrial innovations in Germany," *Research Policy* 28 (4) (1999): 397–422.

54. "Application-oriented research—research that can be put into practice," available at: www.fraunhofer.de/en/research-topics.html (September 2014).

55. Comin and others, "Fraunhofer."

56. "German Federation of Industrial Research Associations (AiF)," available at: www.research-in-germany.de/dachportal/en/Research-Landscape/Research-Organisations/Industrial-Research-Associations-AiF.html (January 2014).

57. Federal Ministry for Economic Affairs and Energy, "Central Innovation Programme for SMEs" (2014).

58. Bavarian Ministry of Economic Affairs, Infrastructure, "Transport and Technology, Invest in Bavaria: Facts and Figures" (2007).

59. The research may not derive utility in the short term but could greatly impact the productivity of an industry in the long run. Comin and others, "Fraunhofer."

60. Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology, "Invest in Bavaria: Support Programs in Bavaria" (2008).

61. This is the largest R&D expenditure increase in reunified German history. Despite having a series of institutions that collaborated to promote innovation and research, the High-Tech Strategy was the first overarching national innovation strategy. The High-Tech Strategy was adopted in 2006, reaffirmed by the Federal Government in 2009 and expanded into the High-Tech Strategy 2020 in 2010.Federal Ministry of Education and Research of Germany, "The High-Tech Strategy For Germany" (2006). Federal Ministry of Education and Research of Germany, "Ideas. Innovation. Prosperity. High-Tech Strategy 2020 for Germany" (2010).

62. Federal Ministry for Economic Affairs and Energy, "Central Innovation Programme for SMEs."

63. Canter and others, "Policy Induced Innovation Networks" 2013. Ezell and Atkinson, "International Benchmarking."

64. National Institute of Standards and Technology, "Connecting Small Manufacturers with the Capital Needed to Grow, Compete, and Succeed: Small Manufacturers Capital Access Inventory and Needs Assessment Report" (2011).

65. Canter and others, "Policy Induced Innovation Networks" 2013.

66. Ibid.

67. Daniel Burton and Kathleen Hansen, "German Technology Policy: Incentive for Industrial Innovation," *Challenge 36* 1 (37) (1993): 37–47.

68. The contents of this sidebar were adapted from a blog post summarizing the visit to ESG. Mark Muro, "Talking Innovation in Munich: An Exchange," *The Avenue*, December 2, 2014 (www.brookings.edu/blogs/the-avenue/posts/2014/12/02-innovation-munich-muro).

69. George Washington Institute of Public Policy and RW Ventures, LLC, "Implementing Regionalism."

70. Philip Toner, "Workforce Skills and Innovation: An Overview of Major Themes in the Literature" (Paris: Organization for Economic Co-ordination and Development, 2011).

71. Soskice, "German Technology Policy, Innovation, and National Institutional Frameworks."

72. Erik Brynjolfsson and Andrew McAfee, "Thriving in the Automated Economy" (Bethesda: World Future Society, 2012).

73. Toner, "Workforce Skills and Innovation."

74. The teachers track the cognitive development of students in key areas such as math and science and prepare recommendations regarding the appropriate type of secondary school. Despite the fact that this recommendation is not the only factor affecting the decision on which school pupils will attend it is de facto a very strong component in the aforementioned decision. Sylke Viola Schnepf, "A Sorting Hat That Fails? The Transition from Primary to Secondary School in Germany." Innocenti Working Paper No. 92 (Florence: UNICEF Innocenti Research Centre, 2002).

75. The U.S. equivalent of lower secondary education corresponds roughly to grades 9-13. The decision on which type of lower secondary school children will attend is reached between parents and local educational authorities with a great weight given to the school recommendation based on the teacher's assessment of student performance. Additionally, different States (Lander) offer additional options for lower secondary schools that combine some aspects of the three main types of lower secondary school. Schnepf, "A Sorting Hat That Fails?". Brigitte Lohmar and Thomas Eckhardt, "The Education System in the Federal Republic of Germany 2011/2012: A description of the responsibilities, structures and developments in education policy for the exchange of information in Europe" (Bonn: Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany, 2013).

76. "21st-Century Workforce Development Models A Minnesota-Germany Dialogue" available at: cges.umn.edu/outreach/21stCenturyApprenticeshipModels.html (January 2014).

77. Federal Institute for Vocational Education and Training, "VET Data Report Germany 2013" (2014).

78. Kathrin Hoeckel and Robert Schwartz, "A Learning for Jobs Review of Germany" (Paris: Organization of Economic Co-operation and Development, 2010).

79. Ibid. Global Cities Louisville-Lexington: Building and Sustaining a Competitive Region, "Panel Discussion on Workforce Development" Brookings Institution, 2014, video available at: www.youtube.com/watch?v=-9w6OVIpZms.

80. Federal Institute for Vocational Education and Training, "VET Data Report Germany 2013."

81. Besides providing the necessary supervision of the system, the industrial chambers guarantee the safety of investing in an apprenticeship. Through a bargaining process the industrial chambers and the employee's organization determine wages levels for different types of workers in an industry. This effectively takes away the possibility of firms to lure away qualified employees with higher wages. Their role is so effective that they also enable inter industry cooperation. Betty Joyce Nash, "Journey to Work: European Model Combines Education with Vocation." *Region Focus* (2012). David Soskice, "Reconciling Markets and Institutions: The German Apprenticeship Model," in Lisa Lynd, ed., *Training and the Private Sector* (Chicago: University of Chicago Press, 1994). Ute Hippach-Schneider and others, "Vocational education and training in Germany: short description." Cedefop Panorama series 137 (Luxembourg: European Centre for the Development of Vocational Training, 2007).

82. Jens Mohrenweiser and Thomas Zwick, "Why Do Firms Train Apprentices? The Net Cost Puzzle Reconsidered." ZEW Discussion Papers No. 08-019 (2008).

83. Daron Acemoglu and Jorn-Steffen Pischke, "Why Do Firms Train? Theory and Evidence." *The Quarterly Journal of Economics* 113 (1) (1998): 79-119.

84. Denis Fougere and Wolfgang Schwerdt, "Are apprentices productive?" *Applied Economics Quarterly* 48: 317-346.

85. Association of German Chambers of Commerce and Industry, "Vocational Education and Training (VET) and the Chambers of Commerce in Germany - and elsewhere" available at: www.rgit-usa.com/fileadmin/ahk_rgitusa/media/Vocational_Education_and_Training/IHK_Berufsbildung_englisch-_Presentation.pdf (January 2014).

86. The BBiG regulates the name of the occupation, duration of training, profile of the training occupation (minimum requirements), overall training plan (outline of the syllabus and time schedule) and examination requirements.

87. Federal Ministry of Education and Research, "Dual Training at a Glance"

88. Ibid.

89. Ibid.

90. Ibid.

91. Ibid.

92. Stephen F. Hamilton and Mary Agnes Hamilton, "Creating New Pathways to Adulthood by Adapting German Apprenticeship in the United States." In Walter R. Heinz, ed., *From Education to Work: Cross-National Perspectives* (Cambridge: Cambridge University Press, 1999).

93. Hippach-Schneider and others, "Vocational education and training in Germany."

94. Federal Ministry of Education and Research, "Dual Training at a Glance."

95. Hippach-Schneider and others, "Vocational education and training in Germany."

96. Toner, "Workforce Skills and Innovation."

97. Soskice, "German Technology Policy, Innovation, and National Institutional Frameworks."

98. Pisano and Shih, Producing Prosperity, 2012. Karl Ulrich Mayer and Heike Solga, *Skill Formation: Interdisciplinary and Cross-National Perspectives* (New York: Cambridge University Press, 2008).

99. Soskice, "German Technology Policy, Innovation, and National Institutional Frameworks."

100. Karan Girotra and Serguei Netessine, "Extreme Focus and the Success of Germany's Mittelstand." *Harvard Business Review*, February 12, 2013.

101. The contents of this sidebar were adapted from two blog posts. Joseph Parilla and Alan Berube, "Training a Next-Generation Workforce in Nuremberg," *The Avenue*, November 24, 2014 (www.brookings.edu/blogs/the-avenue/posts/2014/11/24-workforce-nuremberg-parilla-berube) and Joseph Parilla and Alan Berube, "Lessons from Munich for America's Youth Employment Crisis," *The Avenue*, March 31, 2014 (www.brookings.edu/blogs/the-avenue/posts/2014/03/31-munich-americas-youth-employment-crisis-parilla-berube).

102. Organization for Economic Co-operation and Development, "Government at a Glance, 2013" (2013). Elisabeth Jacobs, "Lessons for the United States from the German Labor Market Miracle" (Washington: Brookings Institution, 2012).

103. Michael C. Burda and Jennifer Hunt, "What Explains the German Labor Market Miracle in the Great Recession?" (Washington: Brookings Institution, 2011).

104. Jelle Visser, "Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 34 countries between 1960 and 2012" (Amsterdam: Amsterdam Institute for Advanced Labour Studies, 2013).

105. Nigel Cassidy, "German apprenticeships: A model for Europe?" *BBC News*, December 13, 2011. "Keeping up with the Schmidts." *The Economist*, April 26, 2014.

106. Mary L. Walshok, Edward Furtek, Carolyn W.B. Lee and Patrick H. Windham, "Building regional innovation capacity: The San Diego Experience," *Industry and Higher Education*, February 2002.

107. Steven Carper, "How do technology clusters emerge and become sustainable? Social network formation and inter firm mobility within the San Diego biotechnology cluster," *Research Policy* 36 (4) (2007): 438–455.

108. CONNECT, "FY2013 Annual Report" available at: connect.org/email/marketing/connect_annualreport_2013.pdf.

109. Michael D. Williams, "Measuring the Impact of Technological Innovation on Sustainable Development in San Diego, World Review of Science," *Technology and Sustainable Development* 2 (1) (2005): 11–34.

110. "Automotive Manufacturing" available at: businessclimate.com/kentucky-economic-development/automotive-manufacturing-(October 2014).

111. "Kentucky's Top Employers" available at: businessclimate.com/kentucky-economic-development/kentuckys-top-employers (October 2014).

112. "Toyota Advanced Manufacturing Technician Program Named Top Career Pathway" available at: www.pltw.org/news/items/201310-toyota-advanced-manufacturing-technician-program-named-top-career-pathway (October 2014).

113. Aspen Institute's event "Skills Training for a Modern Manufacturing Workforce: Does the German Model Have Lessons for the United States?" Consortia Panel available at: www.aspeninstitute.org/video/consortia-solution (June 2014). Project Lead The Way (PLTW) delivers STEM-oriented programs to 5,000 elementary, middle, and high schools in all 50 states and the District of Columbia. For more see the PLTW website: www.pltw.org/about-pltw.

114. "Success Stories: Bluegrass students find fortune in FAME training," available at: www.thinkkentucky.com/workforce/kyFameAMT.aspx (June 2014).

115. "Toyota 2012 Advanced Manufacturing Technician: Work/Study Program Information," available at: www.mclean.k12.ky.us/userfiles/1135/Toyota%20Technician%20Program.pdf (June 2014).

116. Ibid.

117. Jack Brammer and Beth Musgrave, "Beshear asks lawmakers to approve $65 million for Rupp Arena project," *Lexington Herald-Leader*, January 21, 2014.

118. "Toyota Advanced Manufacturing Technician Program Named Top Career Pathway" available at: www.pltw.org/news/items/201310-toyota-advanced-manufacturing-technician-program-named-top-career-pathway (October 2014).

119. Aspen Institute's event "Skills Training for a Modern Manufacturing Workforce: Does the German Model Have Lessons for the United States?" Consortia Panel available at: www.aspeninstitute.org/video/consortia-solution (June 2014).

120. "Inmatech," available at: inmatech-inc.com/ (September 2014).

121. Tom Henderson, "Inmatech sees power in new battery tech", *Crain's Detroit Business,* August 27, 2014. Caroline M. Sallee, Erin Agemy, and Alex L. Rosaen, "The University Research Corridor's Support for Advanced Manufacturing in Michigan" (East Lansing: Anderson Economic Group, 2010).

122. Fraunhofer USA, Annual Report 2013, available at: http://www.fraunhofer.org/Multimedia/www.fraunhofer.org/Files/2013%20Annual%20Report.pdf.

123. Tom Henderson, "Inmatech sees power in new battery tech", *Crain's Detroit Business,* August 27 2014.

124. Alec Friedhoff and Siddharth Kulkarni, "Metro Monitor" (Washington: The Brookings Institution, 2014).

125. Personal communication from Amy Cell, senior vice president of talent enhancement, Michigan Economic Development Corporation, February 11, 2014.

126. "Michigan Advanced Technician Training ($MAT^{2®}$) Program," available at: www.mitalent.org/mat2/ (September 2014).

127. "Gov. Rick Snyder: Investing in skilled trades training strengthens Michigan's economy," available at: www.michigan.gov/snyder/0,4668,7-277--340214--,00.html (January 2015).

128. MAT^2: Michigan Advanced Technician Training, "Pilot – Implementation of Dual Education System in MI" Presented at the MEATA Conference, May 16, 2013.

129. "MAT^2 Company Fact Sheet," available at: www.mitalent.org/lib/Files/Careers/MAT2/MAT2%20Employer%20Fact%20Sheet.pdf (September 2014).

130. MAT^2: Michigan Advanced Technician Training, "Pilot – Implementation of Dual Education System in MI."

131. "MAT^2 Company Fact Sheet."

132. Pennsylvania Economy League and KLIOS Consulting, "Achievement in Uncertain Times: The Economic Impact of Ben Franklin Technology Partners [2007-2011]" (2013).

133. Ben Franklin Technology Partners, "Driving Innovation Every Step of the Way: Annual Report and 30th Anniversary Retrospective" (2013).

134. Ibid.

135. Ibid.

136. Ibid.

137. Deborah M. Todd, "Pennsylvania to sell $100M in tax credits for tech investment," *Pittsburgh Post-Gazette*, July 5, 2013.

138. Robert Lerman, "Training Tomorrow's Workforce: Community College and Apprenticeship as Collaborative Routes to Rewarding Careers," (Washington: Center for American Progress, 2009).

139. "Apprenticeship Carolina: SC Technical College System FAQ," available at www.apprenticeshipcarolina.com/faq.html#1 (June 2014).

140. Robert Lerman, "Expanding Apprenticeship Opportunities in the United States," (Washington: Brookings Institution, 2014).

141. "Apprenticeship Carolina: SC Technical College System FAQ."

142. "BMW Scholars," available at: www.bmwusfactory.com/careers/bmw-scholars/ (August 2014).

143. Brad Neese, "The Evolution of Apprenticeship," available at: www.urban.org/events/upload/Neese-Presentation_Master_060114.pdf (October 2014).

ABOUT THE GLOBAL CITIES INITIATIVE

The Global Cities Initiative aims to equip metropolitan leaders with the information, policy ideas, and global connections they need to bolster their position within the global economy. Combining Brookings' deep expertise in fact-based, metropolitan-focused research and JPMorgan Chase's longstanding commitment to investing in cities, this initiative aims to:

- Help city and metropolitan leaders in the United States and abroad better leverage their global assets by unveiling their economic starting points on such key indicators as advanced manufacturing, exports, foreign direct investment, freight flow, and immigration.
- Provide metropolitan area leaders with proven, actionable ideas for how to expand the global reach of their economies, building on best practices and policy innovations from across the nation and around the world.
- Create a network of leaders from global cities intent upon deepening global trade relationships.

The Global Cities Initiative is chaired by Richard M. Daley, former mayor of Chicago and senior advisor to JPMorgan Chase, and directed by Bruce Katz, Brookings' vice president and co-director of the Metropolitan Policy Program, which aims to provide decision-makers in the public, corporate, and civic sectors with policy ideas for improving the health and prosperity of cities and metropolitan areas.

2015 Global Cities Initiative Convenings:

- Detroit, MI
- Indianapolis, IN
- Salt Lake City, UT
- Washington, D.C.

Launched in 2012, the Global Cities Initiative will catalyze a shift in economic development priorities and practices resulting in more globally connected metropolitan areas and more sustainable economic growth. Core activities include:

INDEPENDENT RESEARCH: Through research, the Global Cities Initiative will make the case that cities and metropolitan areas are the centers of global trade and commerce. Brookings will provide each of the largest 100 U.S. metropolitan areas with baseline data on its current global economic position so that metropolitan leaders can develop and implement more targeted strategies for global engagement and economic development.

CATALYTIC CONVENINGS: Each year, the Global Cities Initiative will convene business, civic and government leaders in select U.S. metropolitan areas to help them understand the position of their metropolitan economies in the changing global marketplace and identify opportunities for strengthening competitiveness and expanding trade and investment. In addition, GCI will bring together metropolitan area leaders from the U.S. and around the world in at least one international city to explore best practices and policy innovations for strengthening global engagement, and facilitate trade relationships.

GLOBAL ENGAGEMENT STRATEGIES: In order to convert knowledge into concrete action, Brookings and JPMorgan Chase launched the Global Cities Exchange in 2013. Through a competitive application process, economic development practitioners in both U.S. and international cities are selected to receive hands-on guidance on the development and implementation of actionable strategies to enhance global trade and commerce and strengthen regional economies.

GLOBAL CITIES INITIATIVE

ACKNOWLEDGMENTS

For their comments or advice on drafts of this paper, the authors thank the following individuals: Scott Andes, Amy Cell, Thomas Duesterberg, Stefanie Jehlitschka, Mark Muro, Volker Rein, Martha Ross, Jonathan Rothwell, and James Stone III. Chenxi Lu, Lorenz Noe, and Elizabeth Patterson provided excellent research assistance. Alexander Jones skillfully designed the graphics. We also thank David Jackson for editorial assistance and Sese-Paul Design for design and layout.

This report is made possible by the Global Cities Initiative: A Joint Project of Brookings and JPMorgan Chase. The program would also like to thank the John D. and Catherine T. MacArthur Foundation, the Heinz Endowments, the George Gund Foundation, and the F.B. Heron Foundation for providing general support for the program's research and policy efforts. Finally, we would like to thank the Metropolitan Leadership Council, a network of individual, corporate, and philanthropic investors who provide us financial support and, more importantly, are true intellectual and strategic partners.

ABOUT THE METROPOLITAN POLICY PROGRAM AT BROOKINGS

Created in 1996, the Brookings Institution's Metropolitan Policy Program provides decision-makers with cutting-edge research and policy ideas for improving the health and prosperity of cities and metropolitan areas including their component cities, suburbs, and rural areas. To learn more visit **www.brookings.edu/metro.**

FOR MORE INFORMATION

Metropolitan Policy Program at Brookings
1775 Massachusetts Avenue, NW
Washington, D.C. 20036-2188
Telephone: 202.797.6000
Fax: 202.797.6004
Website: **www.brookings.edu**

Joseph Parilla
Research Analyst
Metropolitan Policy Program at Brookings
jparilla@brookings.edu

Jesus Leal Trujillo
Research Assistant
Metropolitan Policy Program at Brookings
jtrujillo@brookings.edu

Metropolitan Policy Program
at BROOKINGS

telephone 202.797.6139
fax 202.797.2965
web site **www.brookings.edu/metro**

BROOKINGS

GLOBAL CITIES INITIATIVE
A Joint Project of Brookings and JPMorgan Chase