

BROOKINGS

TENNESSEE




BROOKINGS ADVANCED INDUSTRIES SERIES

DRIVE!

MOVING TENNESSEE'S AUTOMOTIVE SECTOR UP THE VALUE CHAIN

DRIVE!

MOVING TENNESSEE'S AUTOMOTIVE SECTOR UP THE VALUE CHAIN

BROOKINGS ADVANCED INDUSTRIES SERIES

Mark Muro, Scott Andes, Kenan Fikri,
Martha Ross, Jessica Lee, Neil Ruiz, and Nick Marchio

THE BROOKINGS INSTITUTION | METROPOLITAN POLICY PROGRAM | 2013

TABLE OF CONTENTS



BROOKINGS


DRIVE!

MOVING TENNESSEE'S AUTOMOTIVE SECTOR UP THE VALUE CHAIN

EXECUTIVE SUMMARY

More than 30 years ago, Tennessee's economy was transformed by the arrival of Japanese automaker Nissan in Smyrna. Now, $30 billion in investment later and five years after the onset of the Great Recession, an exponentially larger and more intensely competitive Tennessee auto industry has begun to grow again under new conditions. This environment presents Tennessee with both opportunities and challenges as it considers how to secure more and better jobs and prosperity in what the state has recognized as a definitive "advanced industry."

As defined by the Brookings Institution's Metropolitan Policy Program, advanced industries (AIs) like the auto sector are the high-value innovation- and STEM-worker intensive industries that drive regional and national prosperity in the United States.

AIs matter because large and small companies in the sector—including Ford and Johnson Controls in the auto industry and GE, Intel, Medtronic, and Siemens in other industries—generate 11 percent of the nation's output, 46 percent of U.S. goods exports, and over 16 million skilled direct and indirect jobs. Similarly, AIs like automotive parts, medical devices, and electronics along with aerospace and scientific research matter because they are the prime site of the nation's R&D enterprise, which has enabled a steady stream of life-transforming innovations ranging from hybrid cars, air flight, and GPS to LASIK, MRIs, and clean energy.


BROOKINGS ADVANCED INDUSTRIES SERIES

However, advantage is in no way assured either in auto or the broader AI sector—for the nation or for Tennessee. In fact, Tennessee's significant AI sector—anchored by its auto industry— enters an era of continuous disruptive change in the global economy with both genuine momentum and vulnerabilities.

On the one hand, the state's increasingly dense and diverse production networks appear extremely well-positioned to expand the state's standing as one of the most competitive platforms for automotive production in the world. Favorable cost structures, a central location, and strong transportation infrastructure place Tennessee near the center of North American auto manufacturing. Meanwhile, one of the continent's most extensive and international supply chains provides the capabilities necessary to facilitate manufacturing excellence.

On the other hand, though, the state's auto sector (and other AIs) will face stiffening competition in the next five years from new entrants and new locations even as it addresses large demands for new content, quality, and innovation—all with little pricing leverage. No longer will an appeal based primarily on low-cost production be sufficient. Instead, the state and its industry will need to supplement their solid cost advantages with compelling new appeals based on productivity and operational excellence, labor force skills, and product and process innovation.

The following report, **"Drive! Moving Tennessee's Automotive Sector Up the Value Chain,"** speaks to the new moment by taking a new look at trends in the state industry and assessing the industry's strengths and weaknesses. It also outlines private- and public-sector strategies to maintain competitiveness and upgrade the industry. Overall, the report finds that:

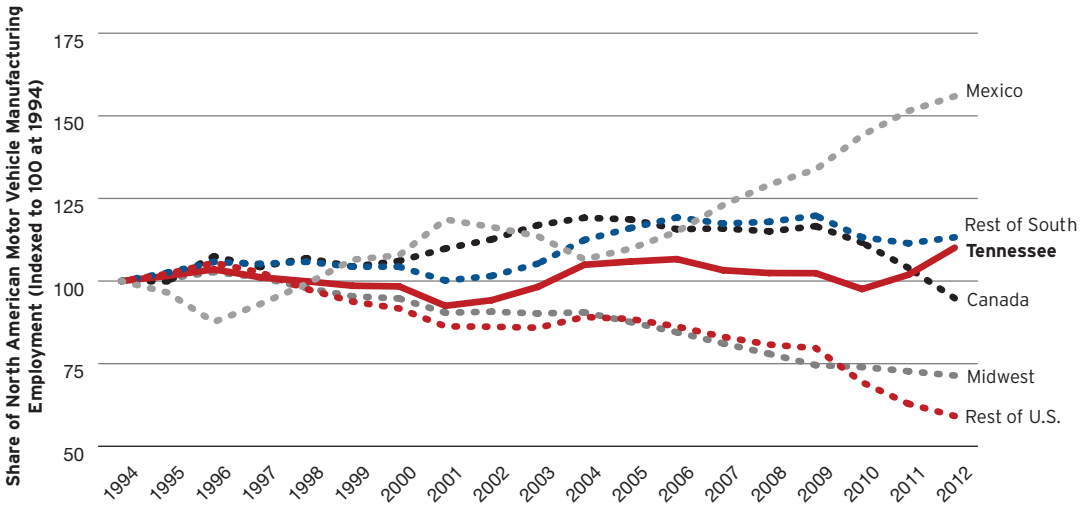
1. FOLLOWING A TUMULTUOUS DECADE, TENNESSEE'S AUTO SECTOR RETAINS SIGNIFICANT MOMENTUM

An analysis of the growth and shape of the state's automotive industry yields new evidence of both the sector's strength and the tough competitive environment it faces. In particular, the new analysis shows that:

- **NOTWITHSTANDING THE 2009 ECONOMIC CRISIS THE TENNESSEE AUTO SECTOR MANAGED TO INCREASE ITS SHARE OF NORTH AMERICA'S AUTO-PRODUCTION MARKET AND LEAD THE STATE'S ECONOMIC RECOVERY.** The state's automotive industry exited the recession and initial slow recovery with considerable momentum. From 2010 to 2012 Tennessee's share of North American motor vehicle manufacturing employment increased from 2.9 percent to 3.3 percent, an all-time high, although employment and output remain below pre-crisis levels. At the same time, employment figures also underscore the significantly faster growth of Mexico as an auto-production challenger. Over the same time period Mexico's share of the North American industry jobs grew from 36.2 percent to 39.1 percent. In any event, the state industry's post-recession momentum has affirmed the auto sector's standing as a prime driver of the Tennessee economy. In this vein, the automotive economy anchors the state's critical advanced industry sector. Currently the largest auto industry in the South in terms of employment, the sector employs one-third of all workers in the state's AI sector—more than any other industry—and generates more output than any other AI as well. The industry has also contributed significantly to the state's employment recovery. Employment in

the automotive industry increased by an average of 16.1 percent each year from 2010 to 2012, compared to 1.8 percent in the economy overall. As a result, the automotive industry has been responsible for more than 12 percent of all job creation in the state since the recession and more than half of all new jobs in the Tennessee AI sector. Similarly, in terms of output the automotive industry has generated more than one-third of the Tennessee manufacturing sector's output growth since 2010 and nearly 85 percent of output since its nadir in 2009

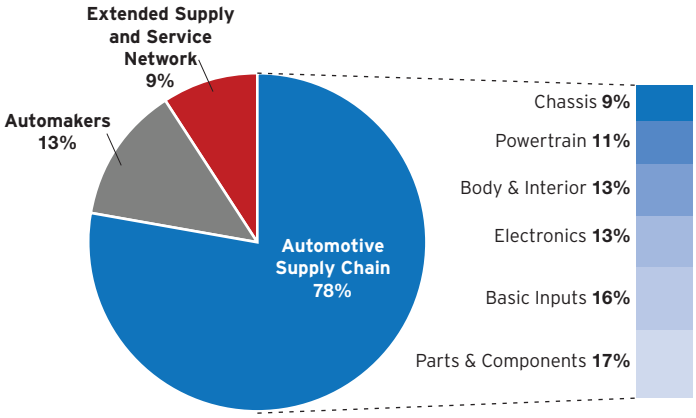
Tennessee's share of North American motor vehicle-related manufacturing employment has held firm throughout a disruptive era



Source: Brookings analysis of data from Statistics Canada, National Institute of Statistics and Geography, and Moody's Analytics

- **TENNESSEE'S LARGE AUTO SECTOR ENCOMPASSES AN EXTENDED PRODUCTION NETWORK AND SUPPLY CHAIN.** New establishment-level analysis conducted for this report reveals that nearly 650 discrete places of business make up Tennessee's automotive economy and together employ almost 94,000 workers. Three name-plate automakers—General Motors, Nissan, and Volkswagen—have major operations in Tennessee and represent each major global auto-producing bloc. These original equipment manufacturers (OEMs) employ more than 12,000 Tennesseans. And yet, notwithstanding the usual focus on the automakers themselves, suppliers actually constitute the bulk of establishments and employment in the industry. Some 73,500 jobs—78 percent of the sector total—reside in Tennessee's direct supplier network, while another 8,500 can be found in a more extended network of indirect suppliers and service providers, meaning that Tennessee ranks first in the South and fifth among peer states in terms of its total supply chain employment. More than half of these jobs reside in the state's approximately 600 small and medium-sized establishments (SMEs), which together employ 49,500 workers. Supply-chain jobs are distributed across companies and establishments involved in producing for every system of the car, with relative specializations in body and interior, chassis, electronics, and parts and components. What is more, the state's auto industry has a strong international cast, with majority-owned foreign businesses from 14 different countries employing 46 percent of Tennessee's auto industry workforce. Taken together, these indicators confirm that Tennessee has emerged as one of the industry's most important supplier hubs not just in the region, but nationally and globally

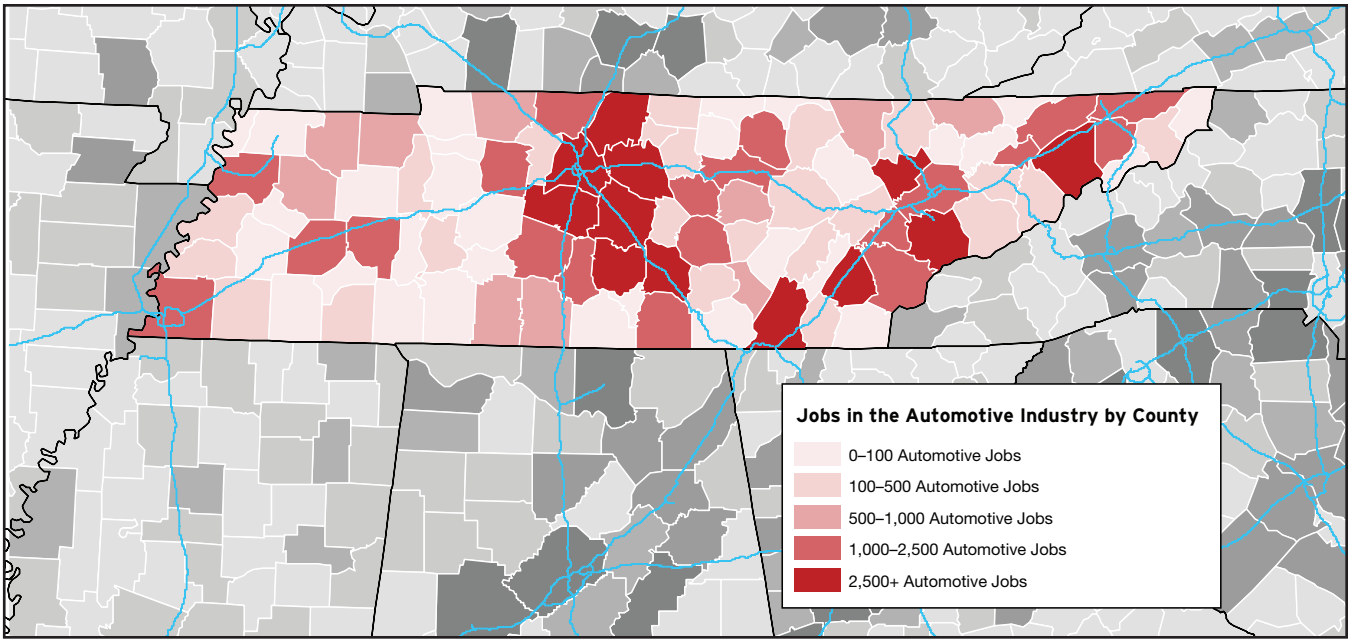
The automotive supply chain accounts for more than three-quarters of industry jobs in Tennessee, building all systems of the car



Source: Brookings analysis of data from Dun & Bradstreet, ELM Analytics, and MarkLines

- **TENNESSEE'S AUTOMOTIVE INDUSTRY TOUCHES EVERY CORNER OF THE STATE.** Finally, the establishment-level analysis confirms that the automotive industry generates considerable economic activity in all of the state's large metropolitan areas, in most of its small metropolitan areas, and in many rural counties. The vast majority of places in the state participate in the auto industry via the supply chain. While automakers employ over 12,000 Tennesseans across establishments of varying sizes in five different counties, the state's extended network of suppliers employs nearly

The automotive industry touches every corner of the state



Source: Brookings analysis of data from Dun & Bradstreet, ELM Analytics, and MarkLines

82,000 Tennesseans whose work is distributed across 80 of the state's 95 counties. Most regions are home to multiple supplier establishments, and most of these establishments produce differentiated products for different systems of the car. Foreign-owned firms are highly regionalized, with over 95 percent of jobs in foreign companies located along or east of the I-65 corridor, and show a slight preference for large metropolitan areas over small ones. In addition, firms of the same nationality tend to cluster near each other. Meanwhile, almost three-quarters of active exporters reside in the state's four largest metropolitan areas

Taken together, these findings reveal that Tennessee's automotive economy is moving into its next phase as a sizable, competitive, and increasingly dense network of producers and suppliers residing in all corners of the state. More expansive, diverse, and diffused than is commonly understood, the Tennessee industry has emerged from the economic crisis with considerable momentum as it embarks on its next era of competition.

2. HOWEVER, DISRUPTIVE FORCES IN THE GLOBAL AUTO INDUSTRY POSE COMPETITIVE CHALLENGES FOR THE TENNESSEE SECTOR

Multiple trends point to continued growth in Tennessee's auto industry. The global automobile market has begun to stabilize and manufacturers are once again forecasting increases in global sales after what has been arguably the worst economic crisis in the industry's history. Growth has been particularly strong within North America. In 2012, U.S. auto sales grew by over 13 percent—the fastest rate in two decades—and created over 250,000 jobs. At the same time, though, fundamental changes in the auto industry are ratcheting up the pressure. At least three megatrends are redefining the very nature of competition in the U.S. auto sector:

- **COST PRESSURES REMAIN INTENSE.** To begin with, cost pressures have continued to ratchet up as input costs steadily rise and consumers demand greater value and content for the same price. Meanwhile, the rise of production in low-cost countries (LCCs) has expanded the field of competition and added to the pressures. At the same time, though, the reality of wage convergence across U.S. locations is at once increasing competition and making it harder for locations to distinguish themselves on low labor costs alone

- **INCREASED PRODUCTIVITY DEMANDS AND SHIFTING DEMOGRAPHICS ARE EXPOSING WORKFORCE CHALLENGES.** The sheer growth and sophistication of the North American auto industry has also increased firms' demand for appropriately skilled workers. While this change is welcome news, it also prompts worries that the current workforce is not sufficiently trained to meet industry demands. Because the productivity imperative requires a uniquely trained and agile workforce, auto industry employers are increasingly looking for workers who are competent at varied tasks, comfortable with technology, and able to remain flexible as process and product innovation proceeds. However, even now employers assert that difficulties in finding workers for skilled production jobs—machinists, operators, and technicians—are reducing firms' ability to expand and employ new technologies. These concerns will only become more acute as auto workers of the baby boom generation begin to retire

- **THE TECHNOLOGY IMPERATIVE IS SHARPENING.** Finally, cost pressures coupled with new regulatory requirements and shifting consumer demand require the implementation of new solutions throughout the entire automobile production system and product line. Of particular concern will be areas that affect fuel efficiency, specifically lightweight materials (particularly carbon fiber) and powertrain efficiency and electrification. In order to be effective, these new innovations will need to penetrate deep into the auto supply chain to firms three and four steps removed from the automaker

Overall, these trends point to a future in which competitive advantage will increasingly require a coupling of cost and efficiency factors with skills and technology factors.

In light of these trends, a systematic assessment of the strengths, weaknesses, opportunities, and threats (a SWOT analysis) of the Tennessee auto industry reveals both sizable assets as well as a number of vulnerabilities. In terms of its assets, the industry seems well situated to flourish. A strategic location, outstanding highway linkages, and a competitive cost structure for heavy manufacturing continue to keep the state competitive. Emergent efforts to bolster the state's global engagement and regional economic development system, paired with pieces of a robust, industry-relevant workforce and educational training system and sizable innovation assets, also bode well for the state.

At the same time, though, ongoing trends expose a number of deficiencies that could imperil the market position of the Tennessee auto industry. At least three challenges raise questions about the near- to medium-term competitive position of the industry:

- **ELEMENTS OF PRIVATE- AND PUBLIC-SECTOR STRATEGY REPRESENT MISSED OPPORTUNITIES FOR INDUSTRY GROWTH.** By and large Tennessee maintains an extremely competitive environment for private-sector firms. However, establishing and maintaining a business-friendly environment for advanced industries such as the auto industry requires industry and government to work together to promote a lean but also strategic development framework. Today, the state is surely lean but on a number of points lacks a truly strategic approach. For example, despite the state's overall favorable ranking on tax competitiveness, Tennessee resides in the bottom fifth of states, according to the Tax Foundation, in terms of its tax competitiveness for new R&D firms and labor-intensive manufacturing. In addition, neither industry nor government fully values the importance of collaboration and exchange among groups of interrelated firms. Instead, the state's development ethos tends to overemphasize the needs of large automakers and underemphasize the supply chain and regional industry clusters. And while the state has made important strides on international engagement, the state could do more to promote exporting and seek foreign direct investment

- **MARQUEE TRAINING PARTNERSHIPS WITH LARGE EMPLOYERS MASK UNEVEN ATTENTION TO THE NEEDS OF SMES AND GAPS IN THE WORKFORCE PIPELINE.** Although Tennessee has begun to construct a comprehensive workforce development system for advanced industries, much work remains. To begin with, Tennessee lags on literacy, numeracy, and educational attainment, which complicates the state's efforts to ensure the availability of a sufficient and appropriately trained workforce for the auto industry. Meanwhile, a careful review of employment and skills demand in auto-specialized occupations reveals a labor market stressed by employers' rising skill requirements and their growing difficulty in finding and keeping appropriately trained workers. This "upskilling" is creating new challenges for the state's workforce training system, which despite recent advances, such as the creation of the Labor Education Alignment Program (LEAP), has yet to debut a cohesive, statewide workforce development system capable of meeting the changing needs of AI employers now and in the years ahead. In this regard, the sector's competitiveness is likely undercut by the variable quality of the education and training programs available to respond to workforce needs of auto and other AI employers. The unfortunate fact: Rather than possessing a fully intentional and AI-focused workforce system, the state instead has a set of cutting-edge, often state-supported one-off programs superimposed on top of a disparate patchwork of regional initiatives

- **LIMITED TECHNOLOGY TRANSFER AND PRIVATE R&D ACTIVITY CONSTRAIN THE STATE'S INNOVATION SYSTEM.** The Tennessee innovation system is anchored by substantial publicly supported R&D activity, led by robust and growing federal and university investments in Oak Ridge National Laboratory, the University of Tennessee, Vanderbilt University, and other research institutions. This provides the state an important base for cultivating a technology edge over the long term. However, a number of deficiencies in the state's innovation and technology

development enterprise limit tech-oriented commercial activity in the auto sector. To begin with, the state's public R&D activity—while robust in general—appears weaker and more nascent when it comes to auto industry-related technology development. At the same time, a paucity of private-sector R&D works to undermine the auto industry's innovation potential. Also of concern is a shortage of strong efforts to facilitate collaborative technology development throughout the Tennessee auto supply chain. The state, in this regard, lacks both rich technology networks and exchanges and a supportive technology development and commercialization process for auto-sector suppliers, particularly those of medium size

3. TENNESSEE INDUSTRY AND GOVERNMENT SHOULD COLLABORATE TO EXPAND AND ENHANCE THE AUTO SECTOR

Despite the noted challenges and growing domestic and international competition the state's prospects are in fact bright. The state's original strengths as a strategic low-cost location equipped with excellent transport links have been enhanced in recent years and now position Tennessee quite well—if it moves with insight and urgency to complement the state's cost appeal with a more skill- and technology-based model of development.

The state's present standing licenses Tennessee to articulate an aggressive goal for expanding and enhancing its auto sector. Specifically, the state should commit itself to a bold vision for the next five to 10 years that declares: **Tennessee will emerge as a premier global destination for high-value automotive production.**

To get there, Tennessee's industry and government leaders need to break with traditional and largely reactive economic development strategies and instead focus more assertively and strategically on targeted interventions aimed at addressing specific industry and policy weaknesses. These strategies should aim to get ahead of the many disruptive changes beginning to roil the global auto industry and to anticipate the coming era in which skills and technology will matter as much as low costs in the auto sector.

Three major strategies for advancing the Tennessee automotive economy—as well as other AIs—suggest themselves. Working together, the state's private sector and public and nonprofit communities should:

- **DRIVE CONTINUOUS INDUSTRY DEVELOPMENT:** Establishing and maintaining the state's competitive edge for advanced industries like the auto industry will require urgent moves to increase firms' operational prowess, foster the broad health of the supply chain, and tap new market opportunities. Along these lines, private- and public-sector efforts to drive increased competitiveness should include, along with continued vigilance on cost structures, new moves to promote the vibrancy of the overall cluster (and not just its automakers), develop forums for information exchange, and promote both exports and strategic foreign direct investment (FDI)

- **DEVELOP THE WORKFORCE PIPELINE TO STRENGTHEN TENNESSEE'S AI SKILLS BASE:** Tennessee faces a skilled worker shortage that threatens to be a pinch point in the industry's growth. A long-term commitment, starting now, that brings together industry and public-sector educational institutions to train, retrain, and attract the workers necessary for the automotive and AI sectors to flourish will be critical in the years to come

- **COMMIT TO INNOVATION AT ALL LEVELS OF THE SUPPLY CHAIN:** With a number of technologically disruptive forces affecting the global automotive industry, the bottom lines of automakers and their suppliers in Tennessee will depend on how well the state's innovation system functions. As such, the state should aggressively support efforts to increase commercialization, incentivize private-sector research, and expand suppliers' access to technology

* * *

Looking to the future, both industry and government should organize an array of actions along the lines of these three strategies. This report recommends the following division of labor among industry and government actors to move the Tennessee automotive industry up the value chain:

- **THE PRIVATE SECTOR MUST LEAD THE WAY IN EXPANDING THE FOOTPRINT OF THE TENNESSEE AUTO ECONOMY AND ADVANCED INDUSTRIES IN GENERAL.** Auto-sector preeminence will hinge above all on the success of the private sector. More than any other stakeholder, Tennessee auto firms possess the drive and know-how that will allow this advanced industry to thrive. And yet, while individual excellence will be imperative, companies will not be able to go it alone. More and more, the firms that excel will be those that most adeptly engage with supply chain partners, engineering and service companies, industry networks, the public sector, and local institutions to drive down costs, cultivate a top-flight workforce, and add superior value through innovation. Along these lines, the state's auto companies should consider a number of strategic options arrayed across the three strategic priorities identified by this report

  To drive continuous industry development, firms should: continue to **increase competitiveness through operational excellence** and make that a hallmark of Tennessee auto manufacturing. Tennessee auto industry companies should also step up their engagement in industry-wide networking and, more specifically, **play a lead role in developing a more robust industry association** in the state. Meanwhile, Tennessee auto firms should look beyond operational strength and improved cluster dynamics to maximize their present competitive position by **exploring opportunities for expansion into foreign markets and adjacent industries**

  To develop the workforce pipeline to strengthen Tennessee's AI skills base, firms should: **seek collaborative solutions to workforce training needs** that build on their existing associations, partnerships, and self-interest to formally identify and respond to existing and projected industry-wide labor demands. More concretely, firms in the Tennessee auto sector should **lead in developing improved regional skills partnerships** that bring together key stakeholders for the purpose of strengthening the regional workforce pipeline. At the same time, auto and other AI firms should move to develop or expand their relationships with area educational institutions to increase the number of work-based learning opportunities

  To commit to innovation at all levels of the supply chain, firms should: **concentrate on innovation** as a primary tool for value creation, whether to deliver process gains, unique capabilities, or new product offerings. The most concrete way that firms can respond to the innovation imperative is by taking steps to **increase R&D investment**. Meanwhile, Tennessee firms should **prioritize engagement in the innovation commons** and work wherever possible to foster the emergence in Tennessee of a dynamic, multi-channel technology ecosystem in which OEMs, suppliers, business associations, universities, labs, economic development groups, and government interact to deliver innovation gains faster and cheaper than otherwise possible

- **AT THE SAME TIME, THE PUBLIC SECTOR MUST CREATE A SUPPORTIVE ENVIRONMENT IN WHICH AUTO OEMS AND THEIR SUPPLIERS CAN FLOURISH.** The public sector—and especially state government—has its own critical role to play as Tennessee auto companies seek to move up the value chain. A new stance is required—one that is catalytic and facilitating (rather than all-determining) at the state level and supportive and empowering at the federal level. As such, the state—in collaboration with industry and in close partnership with Tennessee's congressional delegation—should organize its next automotive efforts around the three strategic themes described in this report

  To drive continuous industry development, the state should: update its general approach to industry development so as to **focus on groups of firms, SMEs, and the supply chain** much more than it does now. In terms of implementing

THE FEDERAL GOVERNMENT MUST DO ITS PART

The State of Tennessee is recommitting itself to advancing the state's automotive industry (and other AIs) through partnerships and initiatives that catalyze industry development, enlarge the AI skills workforce, and upgrade the state's innovation assets. For its part, the state's congressional delegation should push for federal policies that set a platform for growth and support the goals of the renewed industry-state partnership.

- To drive continuous industry development, the federal government should **reform the U.S. corporate income tax rate** to bring the effective rate in line with competitors while at the same time moving to **institute an investment tax credit for new capital equipment and software**. At the same time, the federal government should **fund and expand programs that catalyze regional AI cluster initiatives**. Likewise, steps to **better support and align export promotion programs** and to **promote trade liberalization and expanded market access** will help bolster U.S. firms' competitiveness in the global marketplace, while efforts to **seek program harmonization** will help encourage AI supply chain strength

- To develop the workforce pipeline to strengthen Tennessee's AI skills base, the federal government should **align education and workforce policy reforms** to develop a more coherent education and training pipeline and **create a "Race to the Shop" competition** to reward bottom-up, business-led creativity in modernizing the regional delivery of federally funded AI workforce education and skills training. At the same time, the federal government should **support employer acceptance and use of industry-recognized certifications** as well as **STEM and career and technical education initiatives** that bridge high school and postsecondary education. Lastly, the federal government should move to **expand and coordinate initiatives to inspire and excite elementary and high school students about STEM** subjects, both in school and outside the classroom

- To commit to innovation at all levels of the supply chain, the federal government should **invest in R&D for cross-cutting AI technologies** by moving to double the research budgets of three key science agencies over the next decade. In addition, the federal government should **scale up the National Network for Manufacturing Innovation (NNMI) and create similar translational research consortiums on engineering topics**. Meanwhile, the federal government should **increase funding for the Manufacturing Extension Partnership (MEP) and reorganize MEP as a one-stop shop for all federal SME support programs** while at the same time taking steps to **facilitate and incentivize national labs' interactions with regional industry clusters and SMEs**. Finally, the federal government should make permanent and expand the R&E tax credit to stimulate more private-sector R&D activity in Tennessee and to reflect the intensified, increasingly collaborative nature of the AI innovation game

the new approach, the state should **name a sector lead in state government** to spearhead automotive industry development. Additionally, the state should consider moving to **catalyze the creation of a robust automotive industry association** to market and advocate for the industry and facilitate networking, learning, and supply chain activities. Finally, the state should "go global" and **emphasize international engagement, both by "doubling down" on export promotion and linking export and FDI promotion**

To develop the workforce pipeline to strengthen Tennessee's AI skills base, the state should: **create an AI skills champion** in state government who would be tasked by the governor with promoting a new vision of workforce development for

the state. Tennessee should also **establish an AI skills challenge grant program** to award funds on a competitive basis to strong initiatives in those regions working most creatively to align skills training to industry demand in the state's key industries. Lastly, the state should work with the private sector and educational institutions to **expand access to work-based learning opportunities** within the AI sector

To commit to innovation at all levels of the supply chain, the state should: adopt a new resolve to **prioritize technology development and diffusion** across the auto and AI supply chains. To that end, the state should move to **encourage private-sector innovative activity**, perhaps through the implementation of a state R&D tax credit or an innovation vouchers program to foster R&D among Tennessee's SMEs. The state should also make sure that it leverages the commercial potential of the sizable public R&D activity now ongoing in Tennessee to the fullest by embracing a renewed bid to **encourage technology transfer from the University of Tennessee and Oak Ridge National Laboratory**. Finally, in the moderate to long terms, the state should **continue building its AI knowledge base**, in part by seeking strategic engagements with neighboring states that support regional AI capabilities

* * *

Mastering the current moment will require new thinking and urgent action—and it will challenge all stakeholders to act differently. The state that did pioneering business with Japan to change its future has done this before. It can do it again. ■

INDUSTRY AGENDA

$ = Little to no cost	**$$** = Low cost	**$$$** = Moderate cost	**$$$$** = High cost

Drive Continuous Industry Development

Increase competitiveness through operational excellence	**$-$$$**
Play a lead role in developing a more robust industry association	**$$-$$$**
Explore opportunities for expansion into foreign and non-automotive markets	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Seek collaborative solutions to workforce training needs	**$-$$**
Lead in developing improved regional skills partnerships	**$$-$$**
Increase the number of work-based learning opportunities	**$$-$$$**
Support the use of industry-recognized certifications	**$$**

Commit to Innovation at All Levels of the Supply Chain

Concentrate on innovation	**$-$$**
Increase R&D investment	**$$$$**
Prioritize engagement in the innovation commons	**$-$$**

STATE AGENDA

$** = Little to no cost | **$$** = Low cost | **$$$** = Moderate cost | **$$$$ = High cost

Drive Continuous Industry Development

Focus on groups of firms, SMEs, and the supply chain	**$**
Name a sector lead in state government to spearhead automotive industry development	**$$**
Catalyze the creation of a robust automotive industry association	**$$$**
Emphasize international engagement, both by "doubling down" on export promotion and linking export and FDI promotion	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Create an AI skills champion	**$$**
Establish an AI skills challenge grant program	**$$$**
Expand access to work-based learning opportunities	**$$**

Commit to Innovation at All Levels of the Supply Chain

Prioritize technology development and diffusion	**$**
Encourage private-sector innovative activity	**$$-$$$$**
Encourage technology transfer from UT and ORNL	**$$-$$$**
Continue building the advanced industry knowledge base	**$$$$**

FEDERAL AGENDA

$ = Little to no cost	**$$** = Low cost	**$$$** = Moderate cost	**$$$$** = High cost

Drive Continuous Industry Development

Reform the U.S. corporate income tax rate	**$$$-$$$$**
Institute an investment tax credit for new capital equipment	**$$-$$$$**
Fund an expand programs that catalyze regional AI cluster initiatives	**$$**
Better support and align export promotion programs	**$$**
Promote trade liberalization and expanded market access	**$$**
Seek program harmonization	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Align education and workforce policy reforms	**$**
Create a "Race to the Shop" competition	**$$**
Support employer acceptance and use of industry-recognized certifications	**$$**
Support STEM and career and technical education initiatives	**$$$**
Expand and coordinate initiatives to inspire and excite elementary and high school students about STEM	**$**

Commit to Innovation at All Levels of the Supply Chain

Invest in R&D for cross-cutting AI technologies	**$$$$**
Scale up the National Network for Manufacturing Innovation (NNMI) and create similar translational research consortia on engineering topics	**$$$**
Increase funding for the Manufacturing Extension Partnership (MEP) and reorganize MEP as a one-stop-shop for all federal SME support programs	**$$-$$$**
Facilitate and incentivize national labs' interactions with regional industry clusters and SMEs	**$$**
Make permanent and expand the R&E tax credit	**$$$$**

I. INTRODUCTION

Starting in 1979 the state of Tennessee, recognizing before others that Asian investment in America could spark a U.S. manufacturing comeback, transformed its economic history by launching the Southern automotive tier.

Then-Gov. Lamar Alexander's courtship of Japanese automakers brought the first foreign-owned auto assembly plant to the South: the Nissan plant at Smyrna. Since the production of its first car in 1983, the Smyrna plant has been joined by additional Nissan assembly plants as well as new plants for General Motors and Volkswagen. Billions of dollars of other new investment has flowed into the state, especially supporting the hundreds of GM, Nissan, and VW suppliers that manufacture power steering units in Morristown, transmission parts in Cookeville, and filtration systems and aluminum in Jackson.

Altogether, approximately $30 billion of auto-related investment, procured through foresight and assertiveness, has allowed Tennessee to upgrade its economy in a meaningful way.

But economies are always in flux. Five years after the Great Recession, a leaner and more intensely competitive auto industry is growing under new conditions. The transformed environment presents Tennessee with both opportunities and challenges as it considers how to move farther up the value chain in what the state has recognized as a classic "advanced industry."

As defined by the Brookings Institution's Metropolitan Policy Program, advanced industries (AIs), such as the auto sector, are characterized by high-value innovation and the intensive employment of STEM (science, technology, engineering, and mathematics) workers. These industries are the prime movers of regional and national prosperity in the United States.

AIs matter because large and small companies in the sector—ranging from Ford and Johnson Controls in autos to General Electric in machinery, Intel in semiconductors, and Medtronic in medical appliances—generate 11 percent of the nation's output, 46 percent of U.S. goods exports, and over 16 million skilled direct and indirect jobs. Likewise, AIs like automotive parts, medical devices, and electronics along with aerospace and scientific research are the prime site of the nation's R&D enterprise, which has enabled the production of a steady stream of life-transforming innovations ranging from hybrid cars, air flight, and global positioning systems to Lasik eye surgery, magnetic resonance imaging, and clean energy.

However, advantage is in no way assured either in auto or the broader AI sector. In fact, Tennessee's significant AI sector—anchored by the auto industry—is entering an era of continuous disruptive change. The state proceeds with genuine momentum, but also has vulnerabilities.

On the one hand, Tennessee's increasingly dense and diverse production networks appear well-positioned to expand the state's position as one of the world's most competitive platforms for automotive production. Favorable cost structures, a central location, and strong transportation infrastructure place Tennessee near the center of North American auto manufacturing. Meanwhile, the accumulation of one of the continent's most extensive, varied, and international supply chains gives the state a formidable repository of the capabilities necessary to facilitate manufacturing excellence.

On the other hand, during the next five years the state's auto sector (and other AIs) will face intense competition from new entrants and new locations while also confronting proliferating demands for new content and quality, all with little pricing leverage. Currently, the state's auto sector lacks the cohesiveness of the world's great manufacturing clusters, which have the advantage of shared infrastructure and deep networks of information exchange. What is more, questions exist both about Tennessee's ability to deliver the AI workforce that future growth will demand and about the degree to which its firms can furnish the innovation necessary to design game-changing new processes, compete on costs, and develop unique products.

Looking forward, the question is: How can Tennessee once again act presciently and intentionally to advance its position in the global advanced industry sector?

This report, a product of significant consultation with numerous auto-industry stakeholders as part of the Brookings Advanced Industries Series, endeavors to furnish insights for the next round of strategy setting. It assembles and analyzes significant new data on the Tennessee auto sector, considers the state's competitive position in light of North American competition and global forces, and suggests an array of private- and public-sector strategies aimed at improving the competitive position of Tennessee's largest AI.

The following chapter sets out the present moment for Tennessee and explains Brookings' approach in developing this report.

Chapters III and IV provide a new, fine-grained picture of the trajectory of the state automotive industry and examine the disruptive trends that are now reshaping the industry globally. These "forces at work" delineate the contours of the competitive landscape with which the state auto industry must contend in order to sustain its competitive position in the years ahead. Chapter V evaluates the strengths and weaknesses of Tennessee's existing assets in automotive in light of the global industry transformations identified in Chapter IV and sets out three areas of industry and policy vulnerability.

The rest of the report articulates strategies and actions.

Chapter VI calls on state actors in the private and public sectors to set a five-to-10-year goal to emerge as a premier destination for high-value automotive production. Chapters VII and VIII present a set of actions that industry and government, respectively, should take to execute on that vision. Chapter VIII, which attends to needed efforts on the part of the public sector, also highlights critical federal actions that can support the development of Tennessee's auto industry and its AI sector more broadly.

The study team behind this report believes that, although the state has much work to do, it possesses the track record and commitment to act again with prescience and urgency to enlarge Tennessee's presence in the global AI sector. The hope is that the information, strategies, and recommendations presented here will assist the state's private- and public-sector leaders as they converge to begin this work.

II. TENNESSEE SHIFTS INTO DRIVE

Ever since Gov. Lamar Alexander's groundbreaking trips to Japan launched the Southern auto tier and initiated over three decades of bipartisan industry development, Tennesseans have maintained a keen interest in the auto industry. During this time, Tennessee governors and legislators from both parties have collaborated to support what has become a world-class automotive economy.

State leaders have helped deliver steady growth in the sector, from Nissan's continued investment in its Smyrna and Decherd facilities to the reopening of the GM plant in Spring Hill and the construction of Volkswagen's $1 billion assembly plant and state-of-the-art Volkswagen Academy in Chattanooga.[1] Over time the state has enjoyed close to $13 billion in investment from these automakers and billions more from scores of major auto-sector suppliers.

Now, in the wake of the Great Recession and building on growth in 2012 in gross domestic product (GDP), personal income, and manufacturing jobs, Tennessee is intent on consolidating its position in advanced industries in general and the auto industry in particular. Under Gov. Bill Haslam, the state has expressed a determination to strengthen its industry assets and foster economic growth by making Tennessee, in the words of the governor, "number one in the Southeast for high-quality jobs."[2]

To that end, the state is working to ramp up its economic development, education, and technology activities in order to maximize its competitiveness. These efforts are focused on a number of advanced manufacturing and services industries.

By embracing a regional approach and focusing on key industry clusters, the state's leaders are working to leverage the distinctive assets of Tennessee's metropolitan areas while at the same time bolstering existing strengths in critical industries, including automotive.

The state's renewed emphasis on forging stronger connections between educational attainment and economic development aims to prepare Tennesseans for employment opportunities today and in the years ahead. At the same time, strong support for entrepreneurship and innovation activity provided by the Innovation, Commercialization, Investment, Technology, and

Entrepreneurship (INCITE) fund and the LaunchTN partnership (which focuses on high-tech startups) seeks to ensure that Tennessee is well positioned to capitalize on innovations developed in the state. Programs such as the autoXLR8R entrepreneurial boot camp offered by the Southern Middle Tennessee Entrepreneur Centers demonstrate a specific commitment to commercialization of new automotive technologies.

More recently, the creation of TNTrade, a new export promotion program within the state Department of Economic and Community Development (ECD), and the passage of authorizing legislation for the Labor Education Alignment Program (LEAP) reveal Tennessee's redoubled attention to global engagement and industry-driven workforce development.

Moreover, Tennessee's involvement in the nascent Southern Automotive Research Agenda, proposed by the Michigan-based Center for Automotive Research, suggests a new, more intentional effort to strengthen advanced manufacturing.

Underpinning these varied efforts is a recognition that certain "advanced industries" possess a greater capacity than others for quality job creation and sustainable economic growth.To this end, the state of Tennessee sought fresh insights into the dynamics of its automotive industry as well as an action plan for strengthening all levels of the state's auto manufacturing supply chain and, by extension, the competitiveness of Tennessee's advanced industry base. A key question was: How can Tennessee not only maintain its position in an increasingly competitive North American auto economy but also complement its strong production-oriented operations with higher value-added?

What are advanced industries?

The Metropolitan Policy Program at Brookings defines advanced industries—of which auto manufacturing is one—as those characterized by both a high STEM-skilled workforce and above-average R&D intensity.

AIs are the "crown jewels" of nations, states, and regions.

Encompassing the nation's most sophisticated manufacturing and service industries, the 23 discrete industries that compose the AI super-sector drive and deploy technological advancement; anchor regional and national economic development; and through significant exporting and high-wage employment hold the key to reducing the trade imbalance and increasing the standard of living. Advanced industries include those covered in this report such as motor vehicles and motor vehicle parts manufacturing as well as manufacturing industries like aerospace, semiconductors, and medical devices. Additionally, the sector includes such high-end services as scientific research and development; software publishing, data processing and hosting; and management, scientific, and technical consulting.

In Tennessee, auto manufacturing dominates the super-sector and employs 42,600 Tennesseans—more than one-third of the state's AI total. However, other AIs also contribute significantly to the state's prosperity. Management, scientific, and technical consulting is a significant industry in Tennessee, as are computer systems design and medical equipment manufacturing. Together, these three advanced industries employ over 38,000 Tennessee workers. They also contribute inordinately to the state's economy: Altogether, the AI sector in Tennessee is a $21.3 billion group of industries, responsible for 9 percent of the state's output though it employs just 4.5 percent of its workforce.

And so in summer 2012 the Haslam administration, with the Department of Economic and Community Development serving as point agency, accepted an offer from the Brookings Metropolitan Policy Program to develop a roadmap for advancing the Tennessee auto manufacturing sector, a classic "advanced industry."

Through its Advanced Industries series, Brookings seeks to highlight the critical importance of R&D- and STEM-worker-intensive industries to regional and national economic growth.

The Tennessee project has moved through three distinct phases.

During the *diagnostic* phase, which ran from autumn 2012 through early 2013, Brookings assessed the current position of the Tennessee automotive industry, identified competitive trends, and documented potential opportunities and challenges. As part of this assessment, Brookings conducted a series of one-on-one interviews and in-state listening sessions with a broad array of private- and public-sector stakeholders.

In addition, the Brookings team embarked on a singular effort to map the Tennessee automotive industry. After identifying every Tennessee business establishment involved in the auto economy, the team created a highly granular dataset detailing the specific characteristics of these establishments. The team also investigated the various forces at work in the auto industry at the national and global levels in order to gain a better sense of the landscape within which Tennessee's carmakers and suppliers must operate.

The second phase—*ideation*—involved in-depth engagement with business, policy, labor, and other stakeholder communities in order to determine the specific elements required for an effective federal-state-local policy agenda to support the automotive industry. Over the course of winter and early spring 2013, the team developed initial recommendations based on feedback from stakeholders as well as Brookings' own analysis of the strengths, weaknesses, opportunities, and threats facing Tennessee's auto industry.

The last phase—*finalization*—resulted in the preparation of this report, which maps out the contours of the state's automotive industry, describes the key forces affecting industry growth, and sets out actionable agendas for industry and government leaders alike. During this phase, the team worked closely with officials in state government as well as industry stakeholders and other experts to refine the report's findings and recommendations and prepare them for public release.

Subsequent to this release, the report's findings will inform the development of a framing paper on the importance of AIs to the national economy and the steps that federal policymakers can take to bolster the nation's strength in these critical industries. This paper will be released at a public forum in Washington, D.C. in winter 2014.

III. MEASURING TENNESSEE'S AUTO ECONOMY

If advanced industries anchor the Tennessee economy, the iconic automotive industry resides at its center. Currently, the auto sector accounts for over a third of all Tennessee jobs in "advanced" R&D and STEM-knowledge-intensive industries—a crucial swath of industries that ranges from pharmaceuticals and medical devices to aerospace manufacturing, software, and telecommunications.[1]

What is more, a bottom-up establishment-level look reveals that this advanced automotive core depends on a supplier base that is roughly as large in terms of workers—for a total of more than 90,000 Tennesseans. The auto industry matters hugely to Tennessee.

In order to assess the full range and nature of auto industry activity in Tennessee, Brookings utilized two complementary analytic frameworks—one based on conventional industry codes, which enabled comparison across regions and over time; and one built from establishment-level data, which provided important information on the characteristics of each individual automotive production-related business in Tennessee. This dual approach yields a dynamic, detailed, and comprehensive assessment of Tennessee's automotive industry and its competitive position.

The analysis finds that Tennessee emerged from the Great Recession—a once-in-a-generation economic reset—with considerable momentum. However, it also shows that the state's competitive position—and its prospects for moving up the value chain in the auto sector—will come under increasing pressure from both peer states and Mexico in the new market environment. Tennessee's peer states are Alabama, Georgia, Illinois, Indiana, Kentucky, Michigan, Mississippi, North Carolina, Ohio, South Carolina, and Texas.[2]

The following discussion summarizes key trends in Tennessee's auto sector today.

Tennessee's auto sector has exited a tumultuous decade of sharpening competition with increased momentum and depth

To begin with, standard industry analysis provides fresh evidence of the continued and renewed significance and vitality of the Tennessee auto sector. Four major findings suggest themselves:

The automotive industry is the single largest component of Tennessee's advanced industry production base and has driven the sector's recovery

The data show that the auto industry anchors the state's critical advanced industries sector. Composed of multiple industries each characterized by high R&D intensity and a high concentration of STEM workers engaged in technology deployment, the AI sector drives innovation and economic development in the United States. In Tennessee, the AI sector currently employs only 4.5 percent of the state's workers but generates 10.9 percent of state output. AIs also led the state out of the recession. These innovation-intensive industries added jobs at an average rate of 4.4 percent each year from 2010 to 2012, compared to 1.8 percent for the economy as a whole. At the same time, the value of AI production increased by 5.3 percent on average annually, more than double the rate of statewide output expansion.

The automotive industry itself, meanwhile, employs one-third of all workers in the state's AI sector—more than any other industry—and generates more output than any other AI as well.

What is more, the automotive industry has been the prime driver of the AI sector's employment recovery. While employment in the AI sector overall increased at a rate of 4.4 percent annually between 2010 and 2012, the two portions of the automotive industry that qualify as "advanced"—motor vehicle manufacturing and motor vehicle parts manufacturing—saw employment grow at average annual rates of 12.5 percent and 9.5 percent, respectively. With these rapid expansions, the automotive industry has been responsible for more than half of all new job creation in Tennessee's AI sector post-recession.[3] In the broader manufacturing sector, the automotive industry alone has accounted for 85 percent of job growth since 2010. Across the entire economy, meanwhile, the automotive industry—employing just 1.7 percent of the state's workforce—has created over 12 percent of all new jobs in Tennessee since 2010.[4] Similarly, in terms of output the automotive industry has generated 36 percent of the Tennessee manufacturing sector's output growth since 2010 and nearly 85 percent since output hit bottom in 2009 (nationally and in Tennessee output reached its low point one year before employment did). Economywide, the automotive industry alone accounts for 13 percent of Tennessee's production increases since 2010 and 20 percent since 2009.

The automotive industry, in short, punches far above its weight in the state's portfolio of advanced industries and represents a critical component of the state's productive sector and innovation enterprise.

Tennessee is home to the fourth-largest concentration of automotive industry employment in the country

At the close of 2012, the automotive industry in Tennessee employed 48,500 workers. Here the automotive industry is defined traditionally according to the North American Industry Classification Scheme (NAICS) as the combination of the motor vehicle manufacturing, motor vehicle body and trailer manufacturing, and motor vehicle parts manufacturing sub-sectors. This concentration confirms Tennessee's position, in terms of employment, as the fourth-ranked auto-producing state in the nation (behind Michigan, Indiana, and Ohio) and the first-ranked in the South (just ahead of Kentucky). Altogether the state's automotive industry contributed $2.8 billion in compensation in 2012, at an average disbursement of $57,000 per worker.[5]

In terms of the industry's output (also known as GDP or value-added) the figure reached $4.7 billion in Tennessee in 2012.[6] Indiana, Kentucky, Michigan, Ohio, and Texas all ended the year with higher automotive industry output in dollar terms than Tennessee. In Alabama, Indiana, Kentucky, Michigan, and South Carolina, meanwhile, the automotive industry is a more significant contributor to total state GDP—meaning that the sector is larger relative to the size of each state's total economy—than it is in Tennessee.

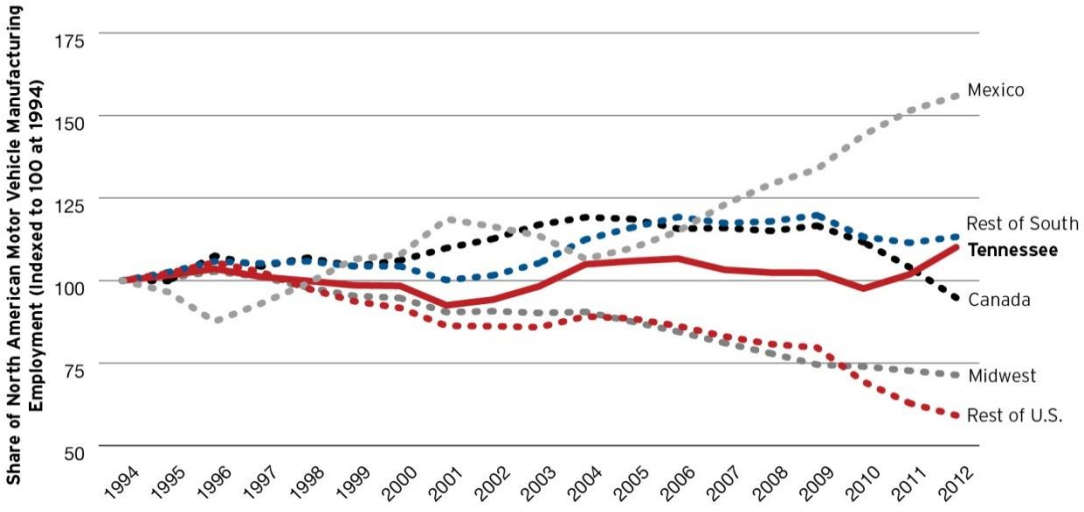
Tennessee managed to increase its share of North America's auto-related employment and output amid one of the most turbulent eras in the industry's history

The Tennessee auto industry has actually increased its market share in the last decade of recession and slow recovery. Specifically, Tennessee managed to consolidate and advance its position in the North American market relative to other regions by moderating job losses during the elongated auto downturn and then recovering them at a faster rate than competitors on the upswing.

During the auto-employment downturn that lasted from 2000 to 2009, Tennessee's automotive employment declined by an average of 5.5 percent per year. When compared to the national industry's faster 5.9 percent slippage, it is clear that the state's job losses—while severe—were restrained relative to the industry as a whole.

On the upswing, however, employment in Tennessee's automotive industry increased by an average annual rate of 16.1 percent a year from 2010 to 2012—a rate faster than any of its peer states except Mississippi, which is home to an industry one-fifth as large. Overall, Tennessee ended 2012 recovering twice as fast as the industry nationwide in terms of jobs. This served to increase Tennessee's share of total North American auto industry employment from 2.9 percent in 2010 to 3.3 percent in 2012—an all-time high. Output figures confirm the state's increased competitiveness: Tennessee's share of North American output increased from 2.8 percent to 3.1 percent over the same period—though by the close of 2012 it still

Tennessee's share of North American motor vehicle manufacturing employment has remained constant throughout a disruptive era



Source: Brookings analysis of data from Statistics Canada, National Institute of Statistics and Geography, and Moody's Analytics

remained below the state's peak 3.8 percent share of continental industry output, reached in 2006. All in all, Tennessee successfully weathered the recession and has lately gained considerable momentum in the recovery.

Taking a longer look back over the cycle, Tennessee increased its share of North American auto industry employment from 2.9 percent in 2000 (the recession wiped away the state's gains from the 2000s so that Tennessee ended the decade where it started, relative to the rest of the continent) to 3.3 percent in 2012. During the same period its share of U.S. auto industry employment increased from 4.5 percent to 6.1 percent, and its share of Southern region industry employment increased from 17.6 percent to 18.0 percent.

During the same period Tennessee increased its share of national industry production from 3.5 percent to 5.0 percent, even as faster output growth in neighboring states eroded Tennessee's share of Southern automotive production from 15.0 percent to 14.8 percent.

A shift-share analysis—which assesses how much more (or less) industry employment increased (or decreased) in a given place than it would have had employment levels simply tracked national trends—confirms that competitive factors unique to Tennessee bolstered the industry during this difficult period and resulted in better performance than the North American market as a whole. In other words, a Tennessee location specifically conferred on companies a clear competitive advantage over the past decade.

Continued investment adds to the momentum of the Tennessee auto industry

A steady stream of sizable investment announcements over the course of 2013 post-date the data available for this report but indicate that the global auto industry continues to view Tennessee as a competitive location for auto production.

The year began with expansion announcements from DENSO, HUF North America, Schrader Electronics North America, SL Tennessee, and U.S. Tsubaki Holdings, Inc. Further investments followed in the spring, led by Alcoa's decision to expand its presence in the auto industry by devoting $275 million over three years to the production of aluminum sheeting used in auto production, an investment projected to create 200 permanent jobs as well as 400 jobs during construction. Over the summer, Magneti Marelli opened its new lighting plant, which it relocated from Italy, and began hiring for the 850 positions created by this new facility. Other expansions include a $109 million investment by Calsonic Kansei North America that is projected to create 1,200 jobs as well as investments by ABMA, ARC Automotive, HP Pelzer, Integrity Tennessee, Meiwa Industry, Miller Industries, NHK Seating, Omega Plastics, Quality Solutions Group, United Stainless, Van-Rob Manchester, and VIAM Manufacturing.

Automakers also chose to continue investing in Tennessee-based facilities. Following the April opening of its 250,000-square-foot energy-efficient paint plant in Smyrna, Nissan announced the addition of 900 jobs at its Smyrna facility with Nissan contractor Yates in June. In August, General Motors made known its plans to spend $350 million upgrading the Spring Hill facility, an investment expected to create or retain 1,800 jobs, and in September the firm announced that it would be adding a second shift at Spring Hill as well.

Taken together, these investment decisions speak to the compelling value proposition provided by the Tennessee platform.

Recent trends suggest that competition will intensify in the coming years as Mexico continues its advance and cost differentials between the South and the Midwest shrink

Just as Tennessee finds itself home to a larger share of the continent's automotive jobs than ever before, the competitive challenge from Mexico threatens to stall or even reverse the state's recent relative advances. If Tennessee's momentum is considerable, Mexico's is extraordinary: Mexico's automotive industry has burgeoned in recent years, and its share of all North American industry employment increased from 36.2 percent in 2010 to 39.1 percent in 2012, after breaking the 30 percent threshold only in 2007. The entire South's share, by contrast, stood at 18.2 percent in 2012. The Mexican auto industry has added nearly 100,000 jobs since 2010 and is growing at an average rate of 13.7 percent a year.

A historical analysis of the shifting geography of jobs within the North American industry suggests that Mexico's increasing significance in the auto sector through 2012 has come at the expense of the Midwest—whose share of North American employment contracted from a high of 42.8 percent in 1996 to a new low of 29.7 percent in 2012—and peripheral regions outside of the Midwest, such as the Northeast and West Coast. Southern states, on the other hand, have so far managed the competitive threat from Mexico without ceding relative position in the industry.

Yet Mexico's comparatively shallow recession and positive net growth rate over the decade contrasts starkly with the deep recession, tepid recovery, and net negative growth that beset most U.S. states, including Tennessee. Now that two forces—the initial wave of relocations south of the border and the shorter-term industrywide contraction wrought by the recession—have dissipated, analysts predict that future competition will center on the attraction of new operations of automakers and suppliers intended to build regionalized production platforms for sales across the Americas. In other words, competition is less likely to revolve around a reallocation of existing jobs but rather around winning expansions and openings. With automakers making over $3.5 billion worth of investment in the country's auto industry from 2007 to 2012 even as they consolidated their footprints in the United States and Canada, Mexico's momentum combined with its increasingly dense and capable supply chain, its persistent cost advantage, and its trading relationships may give it a leg up in this competition.[7]

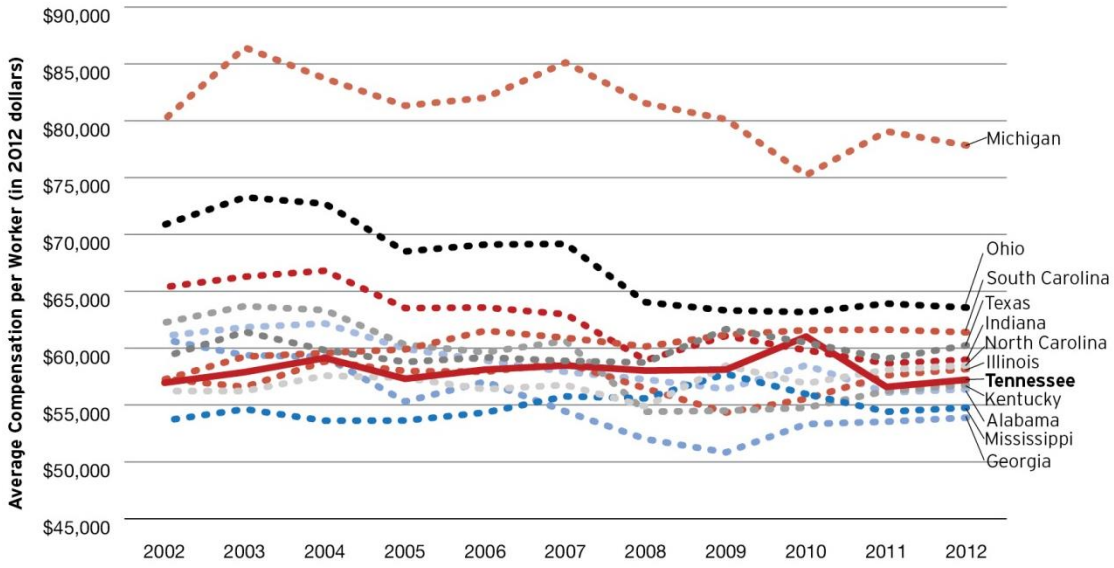
Closer to home, the competition is heating up as well. To begin, Tennessee is not the only state with momentum: The employment recovery in four other states—Georgia, Illinois, Kentucky, and Mississippi—is progressing at an annual average rate of 10.0 percent or higher as well. Increasingly formidable competitors Alabama and Texas—as well as Mexico, for that matter—ended 2012 on the cusp of full employment recoveries, with industry jobs approaching all-time highs. Tennessee, by contrast, ended the year with an industry still only 88 percent of its former size.[8] In this regard Tennessee is not alone: Recession-induced leaning has boosted productivity, eliminated excess capacity, lowered fixed costs, and enabled automakers to produce more automobiles at higher profit margins with far fewer workers than before restructuring.[9] Consequently, even though vehicle sales returned to pre-recession peaks in August 2013, experts expect employment in the industry to recover only a portion of the losses racked up through 2009.[10]

Output measures confirm the momentum behind the industry's recovery in Tennessee but at the same time hint of potential vulnerabilities. After experiencing one of the most severe crashes in percentage terms among peer states, Tennessee's automotive industry output has bounced back, with 25.6 percent annual average growth from 2010 to 2012. Other states have experienced stronger snapbacks, however: Annual average growth exceeded Tennessee's rapid rise in Alabama, Georgia, North Carolina, South Carolina, and Texas. Only the Midwestern states, Kentucky, and Mississippi experienced more restrained recoveries. While output is far more volatile from year to year than employment, Tennessee ended 2012—three years after the market hit bottom—further away from a full output recovery than all but three of its peer states—Kentucky, Mississippi, and Ohio. Production in Alabama and Texas, by contrast, exceeded the highest levels of the heydays of the 2000s.

Along these lines, industry output, or value-added, in Tennessee has been consistently lower over the past decade than would be expected given employment numbers. For Tennessee to remain competitive going forward, value-added per worker will have to rise.

Moreover, the competitive landscape facing states has changed. The recession and the restructuring that it wrought have upended the conventional economics that defined the industry's geography in the pre-recession era. Most notably, Midwestern peer states have emerged from the industry's recent restructuring leaner, more competitive, and more flexible.[11] Tennessee's wage advantage, and that of Southern states generally, has eroded over the past decade as compensation per worker in all major auto states except Michigan (home to many of the highest-paying knowledge and management occupations in the industry) converged around a band between $53,500 and $63,500 per year. To maintain the differential, historically low-wage states and their automakers increasingly rely on even lower-wage pools of flexible contract workers in favor of full-time employees. Post-recession, however, such flexible workforce models are becoming standard. That means that as wage convergence proceeds, other competitive factors like supplier density, labor force skill levels, and proximity to R&D activity could increase in importance.

States will have to find new sources of competitive advantage as compensation levels converge within a $10,000 band outside of Michigan



Source: Brookings analysis of data from Moody's Analytics

Tennessee's automotive industry reveals an extended production network whose center of gravity resides in a vast and varied supply chain

Aggregate industry-level analysis leaves important questions about the nature and composition of the state's automotive industry unanswered.

The very nature of the industry, with its elongated and multi-dimensional supply chain, necessitates an alternative approach to analysis. The U.S. motor vehicle industry itself consumed a massive $393 billion worth of intermediate goods and services from other industries in 2011.[12] Even though these products are manufactured for and ultimately integrated into the automobiles sold to consumers, conventional statistics sweep the business establishments producing these goods into industry categories other than motor vehicle manufacturing.

In order to circumvent this problem and capture the full breadth and depth of the automotive industry in its analysis, Brookings devised a methodology to identify every discrete business establishment in North America and, by extension, Tennessee, engaged primarily in auto-related production. Brookings then obtained information from leading industry intelligence providers including the state of Tennessee for each establishment regarding, for example, size, specialization, ownership, export propensity, and location. The result is an unprecedented high-resolution statistical profile of the industry as it exists in the real economy.[13] (See Appendix A for an in-depth discussion of our methodology.)

Analysis of this database generates a number of significant findings, including the following:

The automotive industry in Tennessee is actually twice the size reported by conventional statistics

The establishment-based approach employed by Brookings generates a detailed picture of the full extent of Tennessee's automotive economy. It finds that the industry is larger than often thought—employing nearly twice as many workers as conventional analyses relying on overly narrow industry classification codes report. In total, Brookings' establishment-based analysis identified nearly 650 discrete places of business that make up Tennessee's automotive economy. Together these establishments employ almost 94,000 workers. In the end, this approach to counting captures over 45,000 more direct automotive industry jobs than does the conventional NAICS-based methodology.

Measuring Tennessee's automotive industry

Conducting an establishment-based analysis of an industry as complex as the automotive industry presents inherent challenges—especially when it comes to defining the scope of a sector that naturally blurs into other portions of the economy. As the degrees of separation between suppliers and automakers increase down the supply chain, company attachments to the industry become more tenuous. Often the automotive industry will be just one of many consumers of the goods and services produced by lower-tier suppliers, be they small machine shops such as Schmiede Corporation or large steel or chemicals companies such as Alcoa or Eastman.

In an establishment-based analysis such as the one conducted here, an establishment must be considered either "all-in," with every job at the establishment counted as part of the automotive industry, or "all-out," with no jobs at the establishment counted. Brookings intentionally erred on the conservative side by excluding establishments where the majority of workers likely could not trace their position directly back to the automotive industry. As a result, Brookings likely undercounts the true number of Tennesseans with connections to the automotive industry, but in exchange is left with a cleaner dataset that can be compared across states.

Brookings' methodology relies on industry codes and propriety lists of suppliers from industry intelligence providers MarkLines, ELM Analytics, and Hoover's to identify automotive industry establishments. Brookings then utilized Dun & Bradstreet (D&B) to provide primary information on each establishment's characteristics, including employment estimates. Brookings relied on these nationally available resources in order to be able to position Tennessee against other states without bias. As a result, however, any establishment not identified by those supplier lists and not in a handful of auto-specific industry codes failed to make it into Brookings' dataset.

The State of Tennessee's Department of Economic and Community Development (ECD), for its part, maintains its own comprehensive directory of all auto-related companies and establishments in Tennessee. Armed with local knowledge,

Measuring Tennessee's automotive industry (continued)

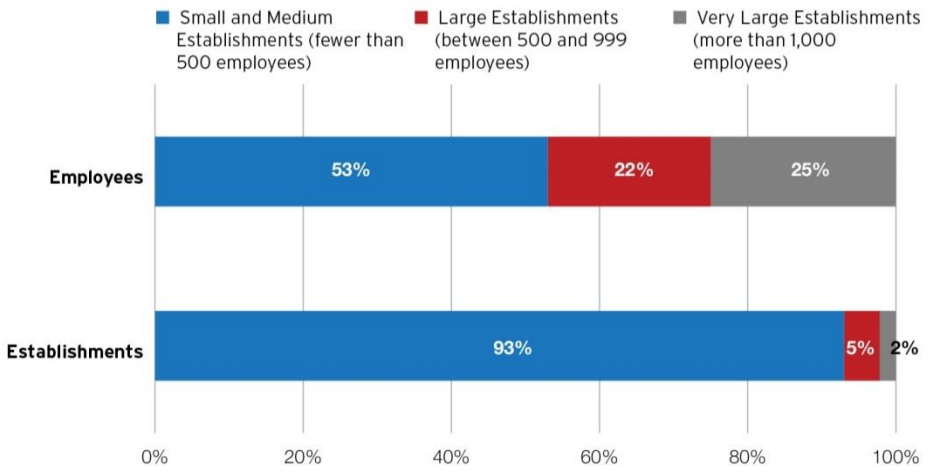
relationships, and government resources such as annual surveys, ECD can identify auto suppliers with much greater precision and nuance than could Brookings. For ECD's purposes—chiefly understanding the many ways Tennessee companies are connected to the industry—a slightly looser criteria for inclusion also makes sense. What is more, ECD enjoys the ability to correct employment estimates and other characteristics of each establishment with the many tools and records it has at its disposal.

Inevitably, these two different establishment-based approaches to measuring the automotive industry yield two different establishment and worker counts. While Brookings' methodology identified 643 individual establishments employing over 93,000 workers in the industry in the state, ECD measures 910 individual establishments employing over 113,000 workers. Ultimately the two numbers are complementary—derived as they are from different sources using different methods and in service of different goals—and come to the same conclusion: that the automotive industry is vitally important to the state of Tennessee. In the end, the discrepancy serves as a valuable reminder of the complexities of industry clusters and the linkages among industries across the economy.

More than half of the state's auto jobs reside in small and medium-sized establishments

Tennessee's approximately 600 small and medium-sized establishments (SMEs)—defined as individual places of business with fewer than 500 workers—employ 49,500 workers, or 53 percent of the total automotive workforce in the state.[14] At the same time, 22 percent of the industry's workforce works in large establishments with more than 500 but fewer than 1,000 employees and another quarter in very large establishments with more than 1,000 employees.

Tennessee's nearly 600 small and medium-sized establishments employ over half of the state's automotive industry workforce



Source: Brookings analysis of data from Dun & Bradstreet, ELM Analytics, and MarkLines

Looking across the South, Georgia and Kentucky exhibit a similar employment distribution across establishment size categories with a slight majority of the workforce employed in SMEs. SMEs employ even larger shares of the workforce—nearly 60 percent—in Mississippi and Texas, while large establishments with more than 500 employees dominate in the Carolinas. In Alabama, the split is nearly even.

In addition to being home to three major automakers Tennessee hosts one of the densest supplier networks in the South

Three name-plate automakers—General Motors, Nissan, and Volkswagen—have major footprints in Tennessee. Altogether, this diversified base of automakers employs more than 11,500 Tennesseans. These companies represent every major global auto-producing bloc, and their product lines are diversified as well, including electric vehicles and batteries (Nissan Leaf), luxury vehicles (Infiniti at Nissan Smyrna), and engines (GM Spring Hill and Nissan Decherd). Beginning in 2014, another major automaker, Daimler, will join Nissan at the Decherd plant in a joint venture to produce engines for Mercedes Benz.[15] This depth and breadth provides the state economy a degree of hedging against the ups and downs of any single company, market segment, or product line.

And yet, notwithstanding the usual heavy focus on automakers themselves, suppliers actually constitute the overwhelming majority of establishments and employment in the industry. What is more, while it is true that many suppliers follow automakers in making location decisions, initial supplier density itself is often considered a crucial location factor in the industry.[16] And so to fully assess Tennessee's competitiveness in the auto industry, an in-depth look at the supply chain is critical.

To this end, assessment of multiple metrics on supplier density shows that Tennessee looks strong relative to its peers on almost all scores.

To begin with, Brookings' establishment-level analysis finds some 73,500 jobs reside in Tennessee's direct supplier network plus another 8,500 in a more extended network of indirect suppliers and service providers, ranking it first in the South and fifth among peer states in terms of total supply-chain employment. (See Appendix C for further detail.)

In terms of the total number of supplier locations, the Tennessee map looks somewhat sparser: Tennessee ranks eighth among peer states with approximately 490 unique supplier establishments. Nevertheless, even on this count Tennessee's supplier density runs higher than in regional peers Alabama, Kentucky, Mississippi, or South Carolina. Taken together, these two counts of jobs and establishments reveal a supply chain with considerable scale in Tennessee.

Meanwhile, on another industry-standard metric of supplier density—the ratio of supplier jobs to jobs at automakers—Tennessee boasts the fourth-highest ratio among peer states with nearly 6.5 supplier jobs for each automaker job, behind Georgia, Illinois, and Texas. (Georgia and Texas, for their part, have few automaker jobs overall and thus a smaller denominator.) Elsewhere in the region, South Carolina has approximately 5.5 supplier jobs for each automaker position, and the ratio falls to 3.0 and below for all other states in the region. To the extent that supplier density runs low in the South, Tennessee bucks the trend.

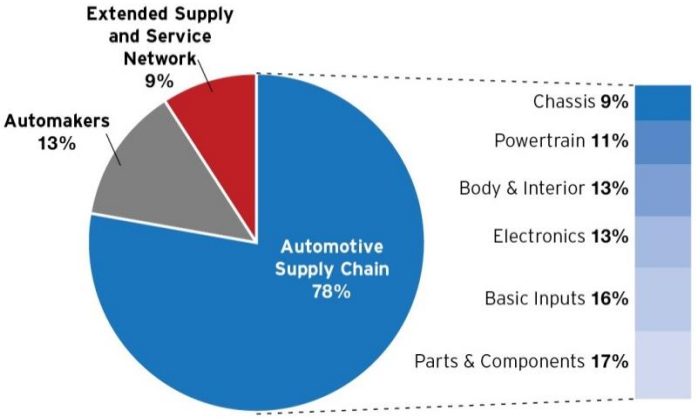
Taken together, these supply-chain indicators show that Tennessee stands out as one of the industry's most important supplier hubs not just in the region, but nationally.

Within the supply chain, Tennessee firms produce for all major subsystems of the car (specializing in four) but engage in relatively little higher-level R&D

Tennessee's 73,500 supplier jobs are distributed across companies and establishments involved in producing for every system of the car. Of the six major categories of supplier—those producing basic materials, bodies and interiors, chassis,

electronics, parts and components, and powertrains—Tennessee's automotive economy is relatively specialized in four: body and interior, chassis, electronics, and parts and components. Aside from Illinois, no other state boasts as many supply-chain specializations and among Southern states only Tennessee and Texas specialize in electronics.

A diverse automotive supply chain accounts for more than three-quarters of auto industry jobs in Tennessee



Source: Brookings analysis of data from Dun & Bradstreet, ELM Analytics, and MarkLines

Parts and components constitutes the largest of these four segments with over 16,000 workers spread across roughly 90 establishments, which include companies such as Calsonic Kansei and ABC Group. Body and interior suppliers employ nearly 12,000 workers across roughly 100 establishments, represented by such companies as Carlex Glass and Unipres USA Inc. Electronics suppliers also employ almost 12,000 workers across approximately 50 establishments, including DENSO Manufacturing and Calsonic. Chassis suppliers—which also encompass firms making the tires that connect to the frame—employ 8,000 workers across nearly 60 sites owned by companies including Bridgestone Tires.

In addition to suppliers, another group of specialized establishments engage in auto-related R&D in Tennessee.[17] These 11 establishments employ over 1,000 workers in the state—only a percentage of whose occupations actually involve R&D—and belong to companies such as Exide Technologies, Henniges Automotive, and Jacobs Engineering. Industrywide, however, R&D activity remains highly concentrated in Michigan, with over 250 separate R&D-conducting establishments; California, with 34 establishments; and the other three Midwestern peer states, with 40 establishments between them. Kentucky leads the South, with 14 business establishments conducting R&D. Texas, for its part, is home to nine private automotive-related R&D facilities, while the remaining Southern states register five or fewer such establishments. In short, while automotive production has decentralized away from the industry's historical core, R&D functions have remained highly clustered. If this trend continues—and the literature on R&D and innovation in the industry suggests it will—Tennessee and its Southern peer states face a difficult journey up the value chain.[18]

More encouraging for the state's efforts to become the industry hub of the South, though, is the number and density of headquarters functions in the state. Eighty-four of Tennessee's 643 business establishments are company headquarters, according to Dun & Bradstreet. In relative terms, this ranks Tennessee sixth nationally and second in the South after Texas. These establishments, owned by companies as large as Nissan North America and Bridgestone, host higher-level corporate functions in addition to production. Having the attendant decisionmaking power situated locally constitutes an asset for a place such as Tennessee, where production activities still dominate.[19]

Foreign direct investment supports nearly half of Tennessee's automotive workforce

The strong international cast of the state's auto industry extends far beyond nameplate original equipment manufacturers (OEMs). Specifically, foreign businesses employ nearly half (46 percent) of Tennessee's auto industry workforce. Altogether, these 43,000 workers work in some 110 separate business establishments, one-sixth of all auto establishments in the state. This concentration indicates that foreign establishments—including those of suppliers—tend to be far larger on average than domestically owned ones.

Such ownership patterns, meanwhile, are not unique in the region. Foreign direct investment (FDI) supports 40 percent or more of automotive industry jobs in a number of Tennessee's peer states including Alabama, Georgia, Kentucky, and South Carolina. Still, after Alabama and South Carolina, where the rate of foreign ownership exceeds 50 percent, FDI supports a greater share of industry jobs in Tennessee than in any other peer state nationwide.

As to the nationality of the enterprises, FDI in Tennessee reflects but is not limited to the significant Japanese and German orientation shaped by the supply-chain linkages of Nissan and Volkswagen, respectively. Along these lines, Japanese firms such as Nissan, DENSO, M-Tek, Bridgestone, Calsonic Kansei, JTEKT, and others account for 71 percent of all jobs in foreign-owned establishments in Tennessee, while German firms such as Volkswagen, MAHLE, Huf, Bosch, and ThyssenKrupp account for another 12 percent of industry employment in foreign-owned enterprises. Canadian firms such as Magna International and Martinrea account for a further 5 percent of the foreign-supported employment in the industry, and French firms such as Hutchinson, Valeo, and Faurecia another 4 percent. The remainder of jobs are spread across establishments whose parent companies hail from England, India, Israel, Mexico, the Netherlands, Norway, and Switzerland. In total, companies from 14 different countries have invested in Tennessee's auto cluster, a number that is average for the region.

In terms of what they are doing foreign-owned firms participate in every segment of the industry in Tennessee. While a quarter of the state's FDI-supported jobs are provided by the major foreign automakers, the remainder are distributed throughout the supply chain. Nearly 9,000 jobs, or about 20 percent of Tennessee's FDI-supported auto employment, are in electronics production, while other jobs focus on parts and components and chassis.

Tennessee is one of the leading exporters of motor vehicles and related parts in the South, but opportunities to boost exporting in the supply chain remain

Tennessee exported motor vehicles, bodies and trailers, and parts with a total product value of approximately $6 billion–7 billion in 2012, ranking Tennessee as the fifth most significant automotive exporter in the country and second in the South, behind Kentucky, with Alabama close behind.[20] Accordingly, Tennessee accounted for approximately 5 percent of total U.S. motor vehicles and parts exports in 2012, in line with its share of total auto-related GDP.

Leading Tennessee's automotive economy into world markets were the major automakers themselves. Nissan, for its part, is increasingly relying on its U.S. production facilities to produce global models and expects to ramp up exports from Tennessee further in the coming years.[21] In 2013 the company added the luxury Infiniti QX60 to the list of models it already exports from Smyrna: the Altima, Leaf, Maxima, Pathfinder, and Rogue. These Tennessee-produced vehicles—many stocked with Tennessee-supplied parts and components—will reach 61 different markets in 2013.[22] In total, the company expects 14 percent of its U.S. production, divided between Canton, MS, and Smyrna, TN, to be exported in 2013. Volkswagen, meanwhile, already produces the Passat for export from Chattanooga to Mexico and Canada and has announced plans to begin exporting the sedan to the Middle East and South Korea as well.[23]

Many Tennessee-based suppliers engage in exporting independently, among them ARC Automotive, International Muffler Company, and Orchid International. Approximate figures based on Dun & Bradstreet information, which may underestimate

the number of firms actually exporting, suggest that Tennessee suppliers are slightly less likely to engage in exporting than those in the Midwest and the Carolinas and Georgia, but are more export-oriented than those in the rest of the South.[24] Altogether, 8.6 percent of Tennessee's auto-related establishments self-identified to D&B as exporters. Approximately 30 percent of these establishments were foreign-owned, most of them large; small and medium-sized domestic producers made up the remaining establishments producing for export from Tennessee.

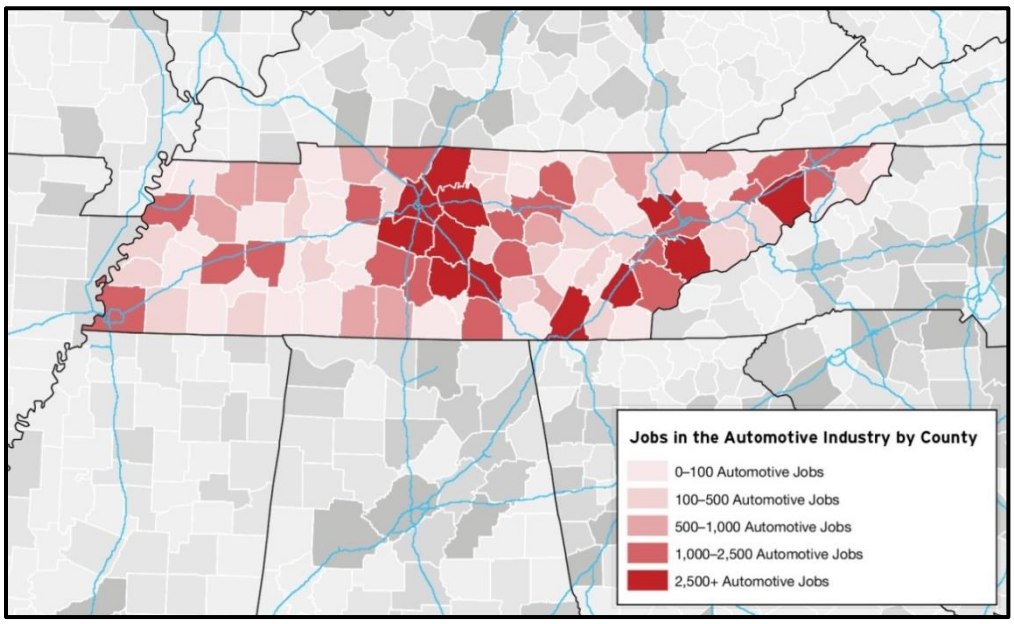
Tennessee's automotive industry touches every corner of the state in varied configurations

As to the location of the Tennessee auto industry, a geographic analysis confirms its remarkable distribution across the state's urban and rural regions:

The automotive industry generates considerable economic activity in large metropolitan areas, small metropolitan areas, and rural regions alike

Of the state's nearly 94,000 auto industry jobs, more than half—48,500 jobs—reside in Tennessee's four major metropolitan areas of Chattanooga, Knoxville, Memphis, and Nashville. Another 36 percent—34,000 jobs—can be found in the state's many smaller metropolitan and micropolitan areas such as Athens, Dyersburg, Kingsport, and Tullahoma. The remaining 11,600 jobs—approximately 12 percent of the total—are spread across 23 rural Tennessee counties in companies such as Magneti Marelli and Manufacturers Industrial Group (MIG) in West Tennessee.

The automotive industry touches 80 of Tennessee's 95 counties



Source: Brookings analysis of data from Dun & Bradstreet, ELM Analytics, and MarkLines

The industry is in this respect ubiquitous. Sliced by region, 53.7 percent of the state's automotive jobs are concentrated in Middle Tennessee—the region stretching from Cookeville, McMinnville, and Tullahoma in the east through Nashville and on to Clarksville and Lawrenceburg in the west. Over one-third—34.8 percent—lie in East Tennessee, and the remaining 11.5 percent can be found in West Tennessee.

The vast majority of places in the state participate in the auto industry via the supply chain

Top-line automaker employment is highly concentrated in relatively few establishments and, as a result, in relatively few metropolitan areas—notably Chattanooga, Nashville, and Tullahoma. However, even with the presence of automakers in these three regions, firms in the supply chain account for the majority of auto-related employment. In Chattanooga, where Volkswagen remains the largest employer, automakers' share of total industry employment reaches just 50 percent. In Nashville—home to major Nissan facilities as well as General Motors' Spring Hill plant—automakers account for only one-quarter of all auto jobs.[25] The share falls to one-fifth in the Tullahoma metro, with Nissan's Decherd facility.

These employment statistics affirm that most places' attachment to the automotive industry runs through the supply chain. While automakers employ over 12,000 Tennesseans across establishments of varying sizes in five different counties, the state's extended network of suppliers employs nearly 82,000 Tennesseans whose work is distributed across 80 of the state's 95 counties.

The average size of supplier establishments varies immensely. A small number of relatively large suppliers characterize the automotive economies in several places, including Athens, Lewisburg, and Shelbyville. Others places, such as Jackson, Johnson City, Kingsport, and Morristown, are home to larger networks of predominantly small suppliers. Memphis stands out as a large metropolitan area with an automotive economy almost completely composed of small suppliers: Its 57 individual establishments—the third-highest count after Nashville and Knoxville—have the smallest average and median size of any major auto region in the state.

Fine-grained analysis reveals a number of specializations within the supply chain across the state

Most of Tennessee's regions are home to multiple supplier establishments, and most of these establishments produce differentiated products for different systems of the car. A look at location quotients—which identify activities that employ a larger share of a region's industry workforce relative to the nation's—reveals a list of supply-chain specializations in each region.

Generally, western metropolitan areas—including Dyersburg, Jackson, and Memphis—specialize in basic inputs, parts and components, and powertrains, represented by companies such as Heckethorn, TBDN Tennessee Company, Mueller Industries, and Setco, an Indian manufacturer.

Eastern metropolitan areas—including Athens, Chattanooga, Greeneville, Johnson City, Kingsport, Knoxville, and Morristown—typically specialize in chassis production, electronics, and to a lesser extent body and interior, parts and components, and powertrain production. Major employers in these regions include DENSO, Sisken Steel and Supply, Robert Bosch, EPIC Technologies, Exide Technologies, SL Americas, IMCO, and Lear Corporation.

Middle Tennessee registers a mix of specializations: bodies and interiors and chassis in Nashville, led by Carlex and Bridgestone, Martinrea, and Accuride; electronics in Shelbyville, represented mainly by Calsonic Kansei; and parts and components in Tullahoma. Cookeville, located between the middle and eastern regions, specializes in electronics, parts and components, and basic inputs. Manufacturers DACCO Inc., Hutchinson FTS, and others operate there.

At the same time, eight different metropolitan and micropolitan areas—Chattanooga, Clarksville, Johnson City, Kingsport, Knoxville, Memphis, Morristown, and Nashville—contain at least one establishment from every supplier segment. The presence of multiple such concentrations of diverse but related activities suggests that the building blocks of competitive industry clusters exist in several of Tennessee's regions.

Cluster dynamics boost innovation, productivity, and growth

Industry clusters are geographic concentrations of firms in the same or related industries along with suppliers, supporting organizations, and related institutions like research universities, national labs, and community colleges.

Clusters matter because the critical mass of entities they encompass catalyzes a number of beneficial but localized dynamics such as labor market pooling, supplier specialization, and knowledge spillovers. These cluster dynamics enhance efficiency; facilitate linkages among customers and between companies and workers; and accelerate the flow of ideas, technologies, and market-relevant information. All firms proximate to the cluster benefit from these positive externalities and derive a degree of competitive advantage simply from "being there." Nor are these synergies theoretical. A review of academic literature reveals broad empirical consensus that robust industry clusters enhance productivity, improve labor-market "matching," and support innovation and entrepreneurship. Ultimately clusters boost regional, state, and national economic performance. They are a fact of supply-chain life.

Sources: Joseph Cortright, "Making Sense of Clusters: Regional Competitiveness and Economic Development"; Mark Muro and Bruce Katz, "The New 'Cluster Moment': How Regional Innovation Clusters Can Foster the Next Economy."

Chattanooga, Knoxville, Nashville, and Tullahoma, meanwhile, also host significant concentrations of activity in lower-tier supply-chain activity in firms such as Ooltewah Manufacturing, Tennessee Tool and Engineering, Parker-Hannifin, and Schmiede Corporation, respectively.

Foreign ownership concentrates in Middle and East Tennessee

Foreign-owned firms are highly regionalized, with over 95 percent of jobs in foreign companies located along or east of the I-65 corridor.

The foreign contribution to total industry activity varies significantly across individual locales. Foreign firms provide more than two-thirds of automotive industry jobs in seven mainly small micropolitan areas in Middle and East Tennessee; between one-third and two-thirds of jobs in seven other metropolitan areas, including Chattanooga, Knoxville, and Nashville; and less than one-third in the remaining regions, including Johnson City, Kingsport, Memphis, and rural Tennessee.

Foreign firms show a slight preference for large metropolitan areas over small ones, with the 22,500 workers in large metropolitan areas outweighing the 20,500 workers in the rest of the state.

Foreign establishments of the same nationality tend to cluster near each other. Most Japanese establishments locate around and to the southeast of Nashville down the I-24 corridor. A second cluster is discernible around Knoxville. Most German companies reside around Chattanooga and the I-81 corridor northeast of Knoxville. Canadian-owned suppliers cluster along I-65 in the center of the state and near German establishments in Chattanooga.

Exporting establishments are overwhelmingly located in large metropolitan areas

Of the 55 establishments identified by Dun & Bradstreet as actively engaged in exporting, 40 of them—almost three-quarters—reside within the state's four largest metropolitan areas. By comparison, the same metropolitan areas contain only 58 percent of all industry establishments, indicating that establishments based in larger metros are likelier to engage in exporting.

Approximately one-fifth of the industry's exporters reside in West Tennessee, and nearly one-third are located in the eastern corridor stretching along the interstate highways from Johnson City to Chattanooga. The remaining half export from locales in Middle Tennessee.

* * *

Conventional and finer-grained data together show that Tennessee's automotive economy is moving into its next phase as a sizable, growing, and increasingly dense network of producers and suppliers residing in all corners of the state. More expansive, diverse, and diffused than is commonly understood, Tennessee's automotive industry is anchored by three major automakers and a number of headquarters with a strong network of suppliers—the largest in employment terms in the South—residing at its core.

In this supply-chain-dominated industry, small and medium-sized establishments employ slightly more than half of the workforce. Suppliers produce for every system of the car, with significant specializations in bodies and interiors, chassis, electronics, and parts and components segments statewide. Foreign investment supports almost half of all jobs in the state's automotive industry, particularly in Middle and East Tennessee. Fewer than one firm in 10 exploits opportunities for export, however, and those that do are concentrated in large metropolitan areas.

The diversity of the state's automotive industry shown here demands an economic development and competitiveness strategy attuned to the industry's diversity and its variety across regions.

IV. OPPORTUNITIES AND THREATS: KEY FORCES AT WORK IN THE GLOBAL AUTO INDUSTRY

Looking beyond Tennessee, it is clear that the state's automotive industry operates amid titanic global dynamics that must be considered when setting strategy. Most notably, the global auto industry has stabilized. At last the industry has begun to see vibrant U.S. sales again and solid growth after the Great Recession.

Moreover, evidence that a period of steady expansion may extend for a few years has started to accumulate. Nevertheless, North American automakers will need to contend with a number of disruptive megatrends as they ramp up production in the coming "new normal" period. These challenging trends represent key features of the current competitive environment in the U.S. auto industry.

Projections of growth for the North American auto industry hold out opportunities for expansion

The first major current sweeping across the industry is benign:

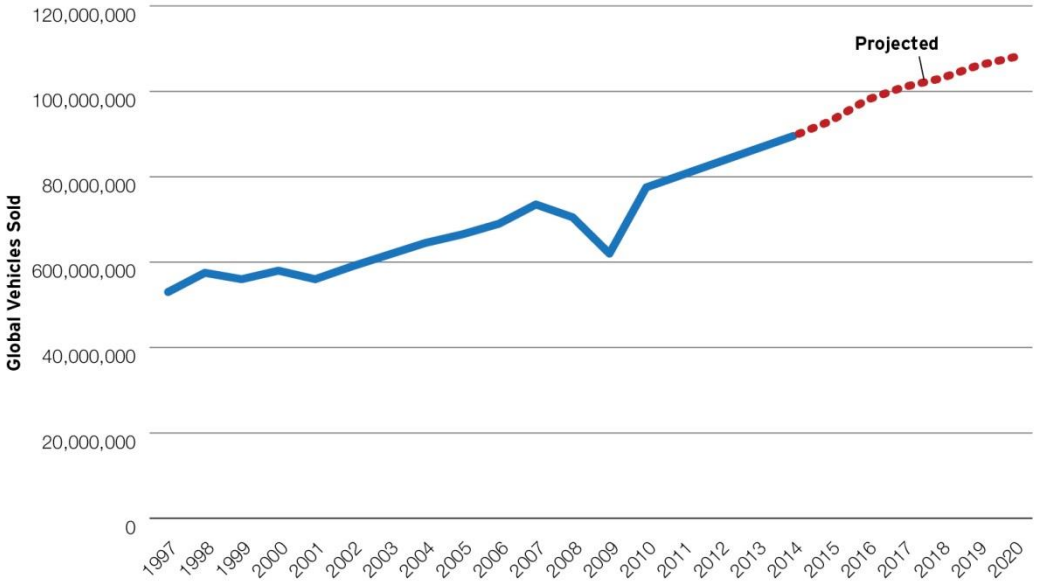
The global automobile market has begun to stabilize, and manufacturers are once again forecasting increases in global sales after what has been arguably the worst economic crisis in auto history.[1] To be sure, two years of contraction and survival by way of extreme cost-cutting and consolidation culminated in a global output decline of 18.5 percent by the end of 2009. In addition, over 300,000 jobs—nearly one-third of total auto employment—were lost between 2008 and 2010.[2]

However, beginning in 2010 a number of forces converged to buoy the global industry. First, capital markets loosened, making consumer financing far more accessible than during the recession. Second, the average age of motor vehicles on the road in the United States has reached an all-time high of 10.8 years, suggesting pent-up demand. And third, emerging markets are growing again and resuming considerably rapid rates of auto purchasing.[3]

Taken together, these forces imply a "new normal" of steady growth in the international auto industry. Growth in sales among developing countries is once again in the double digits.[4] As demand has rebounded and manufacturers clear out overcapacity, production has also swelled.

Global sales grew 4 percent in 2011 and 6 percent in 2012, and they are predicted to grow another 6 percent in 2013.[5] Moreover, pent-up demand has spurred across-the-board price increases in the sector for the first time in over a decade, which has in turn produced higher profits.[6] Indeed, after several years of consistent decline, many suppliers are reporting record profits.[7]

Coming out of the Great Recession the global auto industry has experienced steady growth with more projected for the future



Source: IHS Inc. 2013 and JDA 2012

Growth has been particularly strong within North America. U.S. auto sales grew by over 13 percent in 2012—the fastest in two decades—and created over 250,000 jobs.[8] Following from the thriving American market, Mexico has become a regional hub for many suppliers, and Audi, Ford, Honda, and Nissan recently announced plans to invest $1.3 billion, $1.5 billion, $800 million, and $2 billion, respectively, in production facilities in Mexico.[9]

Industry forecasts suggest the global auto industry will continue to grow to approximately 96 million vehicles by 2016—a 24 percent increase from 2012.[10] While it is unlikely that the United States will reach its former manufacturing peak of 17.8 million vehicles per year (set in 2000) any time soon, the market is expected to return to over 16 million vehicles by 2020—

50 percent above 2009 sales.[11] Some of this growth may outstrip North American sales and reflects Japanese makers' expected relocation of more production to the United States. Auto suppliers also expect continued growth in the near term. According to Lucintel, a global management firm, the international auto component industry is predicted to grow by 25 percent and reach $730.8 billion by 2017.[12] The success of suppliers can be attributed to rapid productivity growth. Within the auto supply chain, labor productivity has grown on average by over 3 percent annually—more than 1.6 percent higher than the U.S. economy as a whole.[13]

Together, global and national trends in the auto industry suggest a growth opportunity for the United States as a whole and Tennessee in particular. Nationally, for example, the reemergence of the U.S. auto industry supported nearly one-fourth of U.S. GDP growth in the first quarter of 2012.[14]

At the same time, a number of disruptive trends make this a critical moment for the auto industry

And yet, notwithstanding the positive outlook, the auto industry is undergoing critical changes that require private-sector leaders and policymakers to adopt new strategies.

Cost pressures continue to affect competitiveness

The first disruptive trend in the auto industry is the continuation of pervasive cost pressures as international competition, input price trends, and increased demand for consumer electronics amplify costs for North American producers.

Global production models and increasing competition require continued cost reductions. To begin with, in order to reduce the costs and complexity of production, global OEMs such as Volkswagen and Toyota are consolidating global models and practices with greater uniformity. Consolidation and simplification allow greater geographic production flexibility, which in turn widens the competitive playing field. Greater competition will almost assuredly lead to additional cost-cutting pressure passed down from OEMs to their suppliers. The 12 largest global automakers are expected to reduce their global platforms (the common design, engineering, and production elements of major components, such as the chassis) from 223 in 2010 to 154 in 2020—which essentially means more cars can be produced in a greater number of places.[15] Fewer regional production lines reduce the comparative advantage of time-acquired tacit knowledge, characteristic of many North American producers, and lower the technological barriers to entry for suppliers in low-cost, emerging markets. Moreover, as international designs are harmonized, OEMs are becoming less hesitant to build production facilities near sites of future demand.[16]

While the old auto industry adage "build where you sell" was a net win for North American producers when the United States was the largest market in the world, the emergence of a stable middle class in China, India, and other developing countries could change that. The convergence of a growing consumer base and rapid industrialization has enabled low-cost countries (LCCs) to attract global OEMs and establish domestic suppliers. Indeed, median income among middle- and upper-class households in China is expected to grow by 20 percent annually over the next decade, thereby tripling the number of potential auto buyers every four to five years.[17] This added consumer base has only amplified global automakers' interest in China. Between 2011 and 2020 China's automotive sector—already larger in terms of sales than the U.S. market—is expected to grow by 8 percent per year.[18] As international markets grow, North American automakers and their suppliers will need to look beyond domestic demand for growth opportunities and diversification.

Because component suppliers follow the sourcing of OEMs, the growth of OEMs in LCCs means parts suppliers are facing price pressure from countries with lower labor and compliance costs. This is particularly true for tier 2 and tier 3 suppliers

of basic components where capital costs are low and processes can be imitated by LCC suppliers.[19] For example, GM's $540 million investment in its Toluca, Mexico plant to produce two engine models will likely precede a number of U.S. powertrain component companies locating in the region to compete with similar American suppliers. This trend toward substitution has, in part, driven a growing trade deficit in auto parts. Since the end of the recession in 2009 imports in auto parts have outpaced exports on average by $32 billion annually.[20]

North American auto production cannot compete with LCCs on labor costs or geographical proximity to growing regional demand. Instead, regional suppliers and OEMs will need to find alternative ways to cut costs in order to remain competitive.

Input costs are rising steadily. Meanwhile, market analysts agree that in the coming decade global commodity prices will continue to rise, notwithstanding the recent downturn in some prices of recent months.[21] In this regard, the prices of steel and petroleum—two of the most important commodities to the auto industry—increased by 30 and 250 percent, respectively, between 2001 and 2010.[22] During that same time period content suppliers were forced to absorb input cost increases of 50 percent.[23] In fact, if not for the recession, which saw commodity prices fall dramatically, raw material prices would have doubled over the last decade. Now, with the global economy somewhat improved, this trend is likely to continue for the foreseeable future. Between 2012 and 2020 the World Bank forecasts that a number of raw materials important to the auto industry will see substantial price increases. For example, Dieter Zetsche, chief executive of global auto manufacturer Daimler, told investors in 2011 that raw materials would add $963 per car to their global cost of production in the coming years.

The changing composition of the modern automobile is also driving up input costs, particularly with regard to IT systems and new battery technologies for hybrid and electric cars. Electronics and communication technologies and batteries require a number of rare earth metals, 90 percent of which are currently refined by China, which strictly adheres to export targets and quotas. For example, in 2010 China suspended rare earth exports to Japan, which caused global prices for neodymium—a rare earth element needed for hybrid batteries—to soar from $50 a kilogram to $500 per kilo by 2011.[24] China's dominance and the absence of multiple supply options increase manufacturers' uncertainty regarding both supply and price of rare earth metals.

Foreign labor costs are also increasing, which raises costs not only for international OEMs but also for U.S. suppliers that add value to basic components imported from abroad. As Chinese, Mexican, and emerging economies become more competitive, wages will rise. In the long run this will reduce these countries' labor cost competitiveness compared to North American workers, but in the short and medium terms such wage increases impose an additional cost to U.S. producers. Indeed, over the last decade labor costs from developing countries within the North American auto supply chain have tripled.[25] On the one hand, auto manufacturers' costs are going up via the labor costs of tier 2 and tier 3 suppliers, while on the other hand, OEMs cannot raise prices out of fear of being undercut by emerging producers in LCCs.

In total, according to research by McKinsey & Company, price increases in new and traditional raw materials as well as labor are expected to lead to a projected additional cost of $1,450 per average vehicle through 2020.[26]

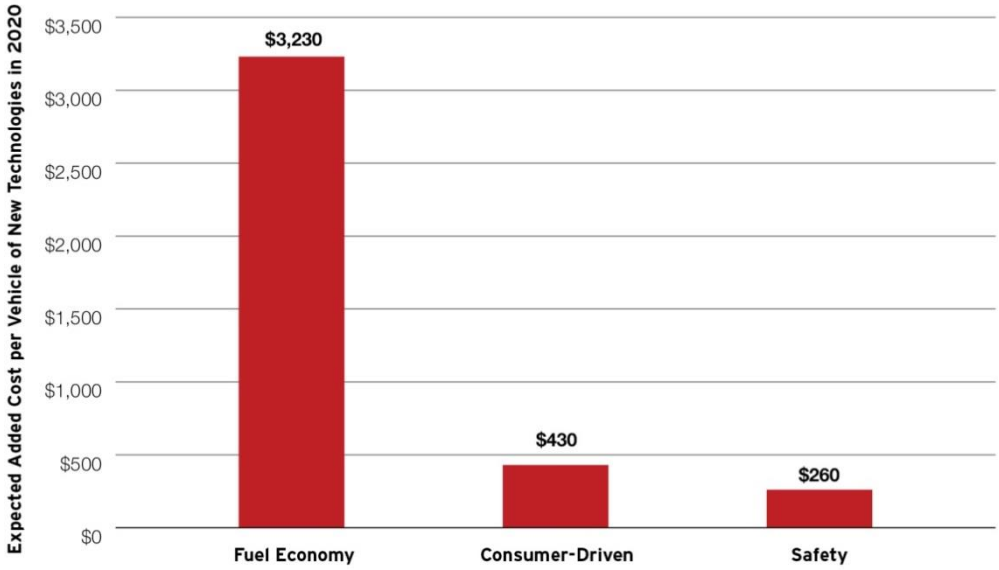
Amid competition and rising input costs, consumers want more content. Simultaneously, as competition and input costs grow, consumers want more value but are unwilling or unable to spend more on automobiles. In just the past few years, a number of new features have become standard on the average American automobile, including front and rear airbags, daytime running lights, cruise control, power mirrors, MP3 ports, and external temperature displays. According to market research by McKinsey & Company, North American automakers and suppliers have had to absorb multiple cost increases in order to meet these new demands. Altogether, added content has increased the cost of production by $1,300 per vehicle on average over the last decade. Yet over the same time period the annual price index for automobiles, light trucks, and utility vehicles has *fallen* by 1 percent.[27]

Unlike in a number of other durable goods industries, the trend in the automotive industry has been toward greater consumer surplus and ability to restrict pricing increases. Consumers can impose such cost pressure in part because of heightened global competition but also due to the growing total fleet of vehicles. Better materials and techniques have increased the durability of automobiles beyond the timespan that the average consumer keeps his or her vehicle, which has

increased the number and availability of used motor vehicles. Analysis by the Center for Automotive Research finds the ability to substitute a new vehicle for a used vehicle or simply to keep one's current auto longer has significantly increased price elasticity—consumers' willingness to forgo a purchase as price increases—in the auto industry.[28]

The trend of increased auto content without increased pricing leverage on the part of automakers will only intensify over the next decade. If over the last decade power components represented added content version 1.0, then in-car communication, telematics, and navigational systems will be added content version 2.0. Wireless broadband and mobile tools have created a sea change across virtually all consumer products, and the modern automobile is no exception. One CEO of a global auto manufacturer argues that, "Soon you will not be able to make money anymore with cars that don't integrate customers' smartphones."[29] Penetration of global in-car telematics is expected to reach 88 percent of vehicles by 2025.[30] While these added systems create value for consumers, they constitute significant additional cost for producers. Currently, electronic and in-vehicle services represent roughly 20 percent of component costs, up from 10 percent a decade ago. By 2020, electronics and infotainment systems are expected to reach 40 percent of total component costs.[31] Future demand for added information technology (IT) content is predicted to increase the production cost per vehicle by an average of $450 by 2020 (in real dollars).[32]

Over the coming decade increased regulation and consumer demand for increased content will further drive cost-pressure for auto producers



Source: McKinsey & Co., "The Future of the North American Automotive Supplier Industry," 2012

Industry growth, sharpening productivity demands, and new production processes necessitate more and differently trained workers

The second global megatrend affecting the North American auto industry is the need for a robust new or retrained workforce. Extreme cost pressure flowing from increased prices and global competition has created a productivity

imperative for North American automakers. The industry must either outperform new global entrants in terms of value per worker or cede market share. The productivity imperative is amplified by the spread of new auto systems and content, such as electrical and infotainment systems, which frequently require skills different from those possessed by the industry's current workforce.

The sheer growth and sophistication of the auto industry in North America has bolstered demand for appropriately skilled workers. Post-recession growth in the North American auto industry has been a boon for auto workers; in the last three years alone the industry has created 250,000 new jobs.[33] While this industry uptick is welcome news, a new generation of workers will need training in a number of next-generation technologies. Shortages of workers possessing the skills training needed for production jobs—machinists, operators, and technicians—may already be reducing firms' ability to expand and employ these new technologies. One industrial study found that 74 percent of manufacturers cite workforce shortages in skilled production roles as a significant constraint to production expansion.[34] These concerns are compounded by the looming waves of retirement among auto workers of the baby boomer generation. While this demographic shift will affect all industries, it will have a particularly pronounced effect on the auto industry, where the average production worker is older than the average U.S. worker. In the industry the average age of a production worker in 2006 was between 50 and 51, compared to the overall workforce average age of 40. Upcoming retirements add to firms' uncertainty and could impede expansion.

The productivity imperative requires a uniquely trained and agile workforce. Meanwhile, industry dynamics are driving sharp new demands for productivity that are making new demands on the automotive workforce. The trend is inescapable. As OEMs reduce platforms and lead time and components become more integrated and complex, North American producers will only be able to maintain their margins by improving productivity through the constant deployment of new techniques, processes, and equipment. This, in turn, will require a shift in the composition of the auto industry workforce toward workers who are competent at varied tasks, comfortable with technology, and able to remain as flexible as R&D progress demands.

To begin with, maintenance and repair workers—those tasked with understanding the mechanics of factory floor machinery and making sure the production process runs efficiently—will need to acquire a number of new competencies. As workers responsible for mechanical maintenance, these workers also make up a large share of the skilled labor pool within parts suppliers. The proficiency required for maintenance and repair employees will be greatly affected by the advent of consumer electronics and IT in automobiles. As a representative of one U.S. automaker put it, "the need for electrical skills is growing almost exponentially due to the increasing electrical/electronic content in the vehicle."[35] What is being dubbed "Car Mechatronics" by technical and community colleges is a growing skill set that couples traditional mechanical knowledge with applied electrical and IT expertise.[36] Some industry observers have even suggested IT and electrical skills will supersede mechanical skills in the future because although many of the traditional functions of a mechanic can be carried out by highly trained electricians, the reverse is not necessarily the case.[37]

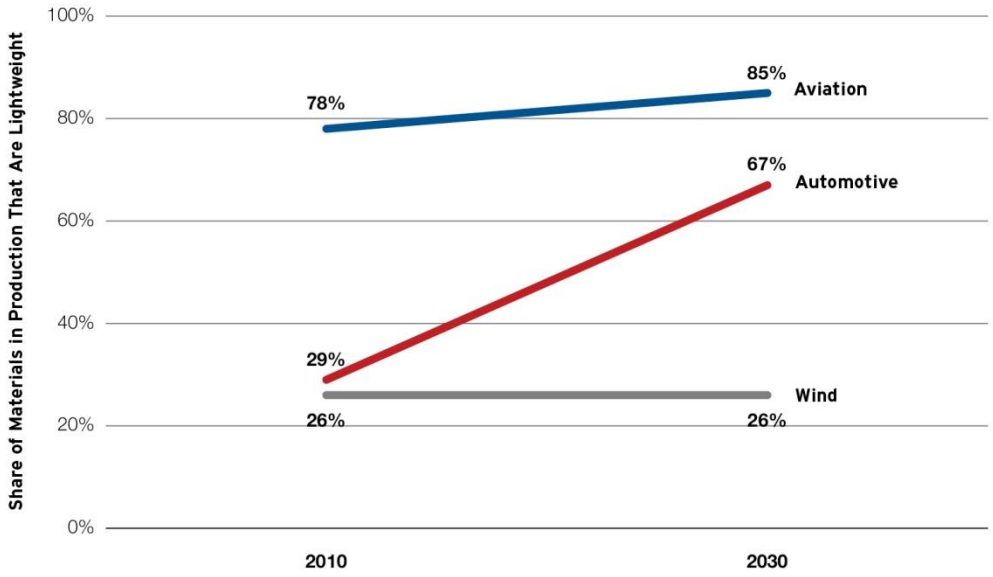
Beyond maintenance and repair employees, meanwhile, workers with advanced engineering backgrounds who are responsible for the design and implementation of new machinery and manufacturing processes will also be affected by the changing technological landscape. At a time when the industry is cutting lead time through lean manufacturing and increased integration among various vehicle systems, the era of Frederick Taylor-style industrial engineers is over.[38] Demand for engineers who "own" a specific operational aspect of the automobile is giving way to "system thinkers." Automakers need industrial engineers with significant experience in simulations and analysis of "big data" (those data sets too large for traditional computing tools). In addition, OEMs are increasingly looking beyond traditional mechanical engineering to diesel engineers, energy management experts, IT professionals, and others who can adapt to radical innovations related to fuel efficiency, electrification, and novel composites.[39] In the past, core discipline was the benchmark for engineering hires. Going forward, interdisciplinary training will be far more important than academic concentration. According to a survey conducted by Deloitte, manufacturers believe that access to a highly skilled and adaptive workforce is the most important challenge facing their firms within the next five to 10 years.[40]

In sum, the workforce stresses produced by new technology platforms represent a clear and present danger to the North American auto sector's competitiveness. Addressing the lack of skilled workers will require greater strategic coordination between public educational institutions and private training programs as well as a move by postsecondary engineering programs to de-silo traditional mechanical, electrical, and chemical engineering departments.[41]

The technology imperative is sharpening

The third megatrend challenging the auto industry is the intensifying innovation imperative now running through the marketplace. Cost pressures coupled with new regulatory requirements and shifting consumer demand have necessitated novelty throughout the entire automobile production line. Of particular concern will be areas that affect fuel efficiency, specifically lightweight materials (particularly carbon fiber) and powertrain efficiency and electrification. In order to be effective, these new innovations will need to penetrate deep into the auto supply chain to firms three and four steps removed from the automaker

Lightweight materials are poised to disrupt the automotive industry most significantly in the two decades to 2030



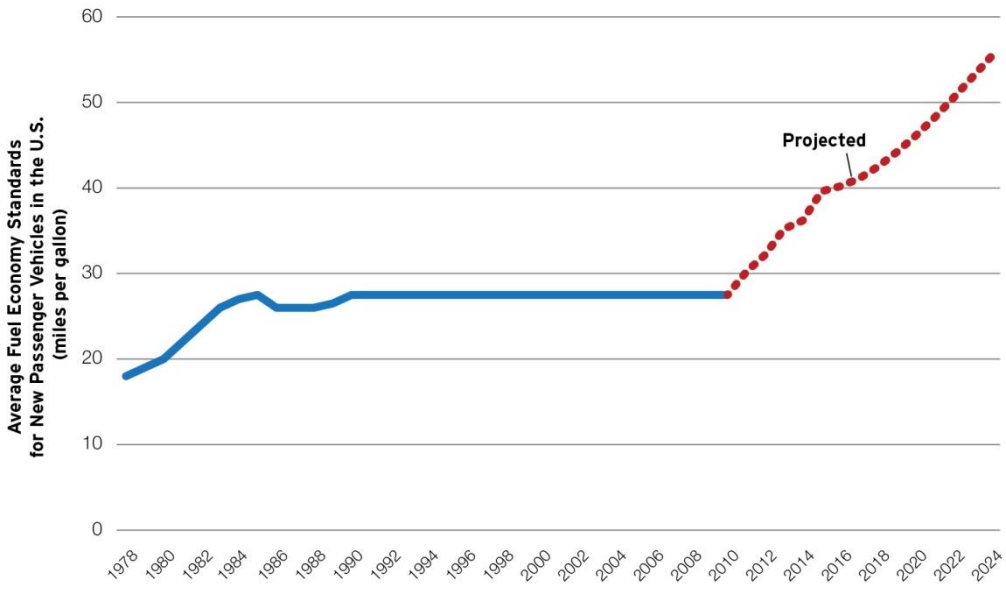
Source: McKinsey & Co., "Lightweight, Heavy Impact," 2012

Cost pressures are requiring relentless technical innovation. Cost pressures are the first driver of the innovation imperative. With consumer willingness-to-pay trends what they are and price increases largely off the table, rapid and ubiquitous technology innovation is the only avenue available to OEMs to both meet customer demand—especially in electronic and IT-enabled components—and address new regulatory mandates. Moreover, labor cost advantages of LCCs and rising raw material costs leave little room to maneuver outside of technological innovation. And so, as new content adds cost and weight to automobiles, automakers are looking for new technologies to reduce the total weight and bring down assembly and material costs.

The technologies that are likely to provide OEMs the greatest cost pressure relief are expected to reside in those parts of the automobile with systemwide implications. For example, many advanced materials that have the potential to increase body strength while reducing weight cannot be joined using traditional bonding techniques. As new design intensifies the interplay between dissimilar materials, technological coordination throughout the supply chain will be essential. These changes are likely to redefine the relationship between suppliers and OEMs. Design control of innovative components will increasingly rest with suppliers, particularly in components that integrate mechanics and electronics. While OEMs will continue to push cost pressure through the supply chain, they will be less able to dictate prices to highly innovative, and thus increasingly relevant, suppliers. There is even some evidence that suppliers and OEMs that synchronize technology platforms in early development may be ahead of the curve in terms of next-generation technologies.[42]

Regulatory demands are intensifying the need for new technical competencies and technological solutions. Regulatory demands are also increasing the innovation challenge. While safety and emission regulations imposed $600 per vehicle in component costs on automakers between 2001 and 2010, stricter rules will likely ratchet up the cost even further in the decade ahead. Indeed, in the absence of new technology, McKinsey & Company research indicates that new safety and fuel efficiency regulations could add as much as $3,200 to the price of an automobile by 2020—almost 16 times the added cost of regulation during the previous decade.[43] Mileage regulations that bring the mandatory mileage per gallon (MPG) standard to 54.5 by 2025 are already making vehicle lightweighting through materials changes essential. In this respect, new regulations are defining "where to play" in terms of technology improvement. For example, synthetic lightweight materials such as carbon fiber create the opportunity for lighter frames and auxiliary components that can meet mileage regulations without sacrificing the heavier powertrains needed for performance. Lightweight materials currently in the R&D pipeline are expected to increase fuel efficiency by 5 to 10 percent for the average automobile.[44] However, greater innovation will be needed to bring down the cost of carbon fiber and other synthetic materials, which are still prohibitively expensive and difficult to bond using traditional welding techniques.

Stringent new fuel economy standards will direct more innovation into powertrain, efficiency, and lightweighting



Source: Center for Climate and Energy Solutions, 2012; U.S. Department of Energy

Turning to the powertrain, it is clear that the group of components that powers an automobile represents potentially the most important prospect for improved performance and fuel economy at lower cost, although over a longer time frame.[45] In this respect, innovations in traditional fuel-injected engines and newer hybrid and electric engines each offer opportunities to radically reduce costs and energy consumption through increased gearing and electrification. Traditional powertrain improvements will predominate in the near and moderate terms. Along these lines, analysis by McKinsey & Company suggests that revenue growth in the auto industry will predominately come from the redesign, development, and manufacture of products that increase fuel efficiency within the powertrain.[46] These new technologies span the full spectrum of innovation in the automotive system, including new low-friction lubricants (e.g. chemical and molecular innovation), continuous variable transmissions (e.g. mechanical and applied physics innovation), electric and battery power (e.g. electrical innovation), and dynamic modeling and performance observation (e.g. computational innovation). At the same time, powertrain electrification is expected to emerge as a burgeoning consumer demand over the next few years, with U.S. demand for hybrid and electric vehicles expected to rise to 2.5 million vehicles by 2016.[47]

North American producers must not only innovate to meet regulatory standards, but also to keep pace with global competitors. The global hub for carbon fiber, a leading materials candidate for near-term lightweighting, is in Japan, and China is currently the largest supplier of magnesium, another important composite for lighter vehicle design. Given the increase in consumer demand, hybrid and battery-electrified powertrains are already on the radar of advanced economies as well as LCCs. According to a survey of global automotive executives conducted by KPMG, the majority of Chinese automotive firms believe electrified powertrains will be the most important technology to Chinese consumers by 2025.[48] Indeed, in 2012, 56 percent of Chinese auto acquisitions were of powertrain firms. Chinese producers' interest in powertrain technology, coupled with massive investment in capital expenditures (as a percent of revenue, capital expenditure investment was three times higher among Chinese automakers than it was among North American companies in 2011), suggest North American producers may already be falling behind in powertrain innovation.[49] To own the critical technologies of the near future, North American companies will have to compete aggressively starting now.

* * *

The global auto industry is changing rapidly. In the coming decade global competition will intersect with escalating input costs and new consumer demand for added digital consumer content. These challenges will enhance price pressures at all levels of the supply chain. At the same time, such forces will produce a clear imperative for a new or retrained workforce with a broad set of skills. Lastly, fuel economy and safety regulations will further ratchet up automakers' costs and force them to make strategic technological bets on lightweighting and powertrain efficiency. More broadly, flexible, systemwide innovation will become increasingly crucial and will replace a legacy of piecemeal component modification.

In sum, the current cost-dominated calculus of firm and regional advantage is giving way to a new regime in which cost factors are inextricably tied to skill and technology themes.

V. ANALYZING STRENGTHS AND WEAKNESSES: TENNESSEE'S COMPETITIVE POSITION

Amid great change and sharpening competition, the Tennessee auto industry approaches the future with strong assets and clear momentum. No state in the South may be better positioned to profit from the growing need of global automakers and top-tier suppliers to locate in North America.

And yet, the industry remains stressed as it negotiates an era in which cost and efficiency factors are increasingly intertwined with skill and technology imperatives.

With both states and nations competing for production work and innovative activity in a highly competitive global sector, Tennessee must contend with a number of deficits in its position.

From certain weaknesses in the state's competitive platform to substantial worker training vulnerabilities and a sub-par innovation ecosystem, these shortcomings must be acknowledged and addressed if Tennessee hopes to gain market share in the next five years.

Which is why this chapter assesses the state's strengths and weaknesses on a number of auto-related indices in relation to national data and the performance of 11 Midwestern and Southern peer states with significant automotive employment. (See Appendix C for the complete results of the benchmarking.) Overall, the chapter concludes that although the state retains many of its original selling points, its ability to maintain position or move up the value chain remains impeded by a trio of significant deficits.

Tennessee possesses significant assets that support its position in the North American auto industry

In many respects, Tennessee remains well positioned to deliver value in North America within a global production system.

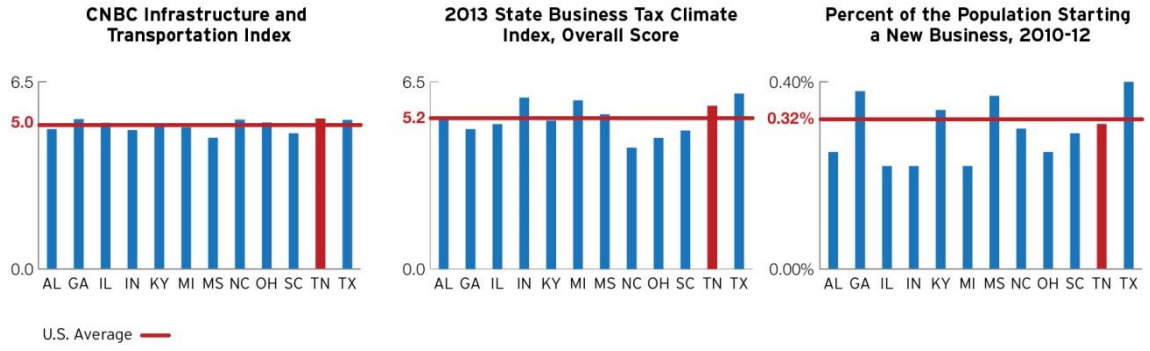
From the beginning, **employer-favorable work rules,** a **central location,** and **strong transportation infrastructure** have made Tennessee a competitive setting for the assembly and distribution of cars.

In this respect, the convergence of I-65 and I-40 in Nashville has allowed automakers in Tennessee to ship products efficiently to and from locations in all directions.[1] In more recent years, the state's transportation connectivity has only improved. Several widenings of existing interstate highways, a new I-75 interchange built in 2009 to connect Volkswagen's new Chattanooga plant to the nation, and the completion of Bicentennial Parkways such as State Route 840 have appreciably improved the state's road network—ranked among the best in the nation in terms of surface quality.[2] Among its peer states, Tennessee also has the second-greatest number of Class I freight railroads, which are critical for just-in-time delivery of automotive parts to manufacturing plants. For all of these reasons, Tennessee ranks second nationally for the quality of its overall infrastructure and transportation access, according to CNBC's "America's Top States for Business 2013."[3]

What is more, the state has in the last two decades emerged as a true super-hub of worldwide logistics and distribution, with the FedEx headquarters located in Memphis and the Port of Memphis standing as the fourth-largest port in the United States.[4] Tennessee's connectedness is further bolstered by the presence of two of the largest trucking firms in the nation—Covenant Transport and U.S. Express Enterprises—which are both based in Chattanooga.[5]

At the same time, the state offers a comparatively **low-cost and predictable environment for manufacturing**. Tennessee receives consistent recognition for its cost advantages, particularly for automakers and suppliers. For example, the state has for four years running ranked first in the nation on *Business Facilities* magazine's "auto manufacturing strength" index, which ranks states based on "growth potential as well as current production statistics and industry trends," including cost factors.[6]

Tennessee offers a competitive setting for the automotive industry



Source: CNBC, "America's Top States for Business 2013"; Tax Foundation, "State Business Tax Climate 2013"; Kauffman Foundation, "Index of Entrepreneurship Activity, 2010-2012"

Tennessee also boasts one of the lowest pre-tax costs of living in the nation, ranking well below the national average in both urban and rural areas.[7] One perennial attraction is the state's lack of a state income tax.[8] Meanwhile, the state's fiscal strength, which reflects strong management over a long period of time by leaders of both political parties, helped ensure that Tennessee had the lowest level of state debt per capita in the nation as of the end of FY 2010.[9]

Thanks in part to these strengths, the state maintains a **growing industrial sector.** Tennessee added nearly 14,800 manufacturing-sector jobs between 2010 and 2012—more than any other state in the Southeast—and its annual average manufacturing job growth rate ranked 18th nationwide. At the metropolitan level, Nashville, Chattanooga, and Knoxville all ranked in the top quintile of large metros by posting strong annual average growth in manufacturing jobs (5.6 percent, 4.6 percent, and 3.8 percent, respectively) during this same period.

With this industrial momentum has come a new ability to **attract skilled workers**.[10] Between 2000 and 2009, Tennessee's population increased by 13.2 percent, with the average level of academic attainment by foreign workers entering Tennessee ranking highest among its peer states, and that of workers migrating from other states the fourth highest.[11] The greatest flows of domestic migrants into Tennessee come from Alabama, Georgia, Kentucky, and North Carolina—all states where manufacturing is a leading industry.[12] Moreover, the state's foreign-born population has surged 93 percent since 2000—faster than any other state.[13]

As to its policy framework, the state has been working steadily in recent years to build a strategic, competitive set of initiatives in economic development, workforce training, and technology development and diffusion.

On economic development, Tennessee has worked hard to cultivate a **can-do, business-friendly economic development stance**. Since the arrival of auto manufacturers in the state, every governor has made an active effort to expand the state's automotive industry and cumulatively they have attracted over $30 billion in private capital investment.[14]

Gov. Bill Haslam has expanded these efforts, starting early on when he filled key cabinet and other positions with accomplished private-sector executives. Haslam has also sought to modernize and focus the state's AI activities by implementing Jobs4TN, which has made existing businesses and key industry clusters (including the auto industry) a priority for ECD's economic development work and instituted a **decentralized, region-oriented economic development strategy** designed to catalyze "bottom-up" economic growth within nine regional jobs base camps.[15] ECD works closely with local partners in each of these camps to develop regional economic development plans and align federal and state resources in support of these plans.[16] To further these efforts, the $50 million Innovation, Commercialization, Investment, Technology, and Entrepreneurship (INCITE) program was created to catalyze, coordinate, and fund—as its name suggests—innovation, commercialization, entrepreneurship, and co-investment activities across the state's nine regions.[17] While parts of this strategy are still in the midst of implementation, the Tennessee leadership's recognition of the centrality of regional clusters and local business networks to economic growth marks an important advance in the state's approach to economic development.

On workforce development, the state has several **pieces of a robust, industry-relevant workforce and educational training system** in place. Increased funding in recent years has enabled the emergence of a number of promising initiatives designed to bolster educational performance and attainment. In 2010, Tennessee received $500 million from the federal Race to the Top program, the largest award received by any state on a per capita basis.[18] These funds support a variety of activities, including several efforts to strengthen the education and training pipeline for advanced manufacturing.

At the same time, the state has worked to improve student access to postsecondary education through the creation of the Tennessee Education Lottery Scholarship Program.[19] Part of this program, the Wilder-Naifeh Technical Skills Grant, provides occupational skills training funds of up to $2,000 per student per year to study at a Tennessee College of Applied Technology (TCAT). Over the course of the 2011–2012 school year, Wilder-Naifeh grants supported 10,928 students, up from 8,815 in the program's first year (2004–2005).[20]

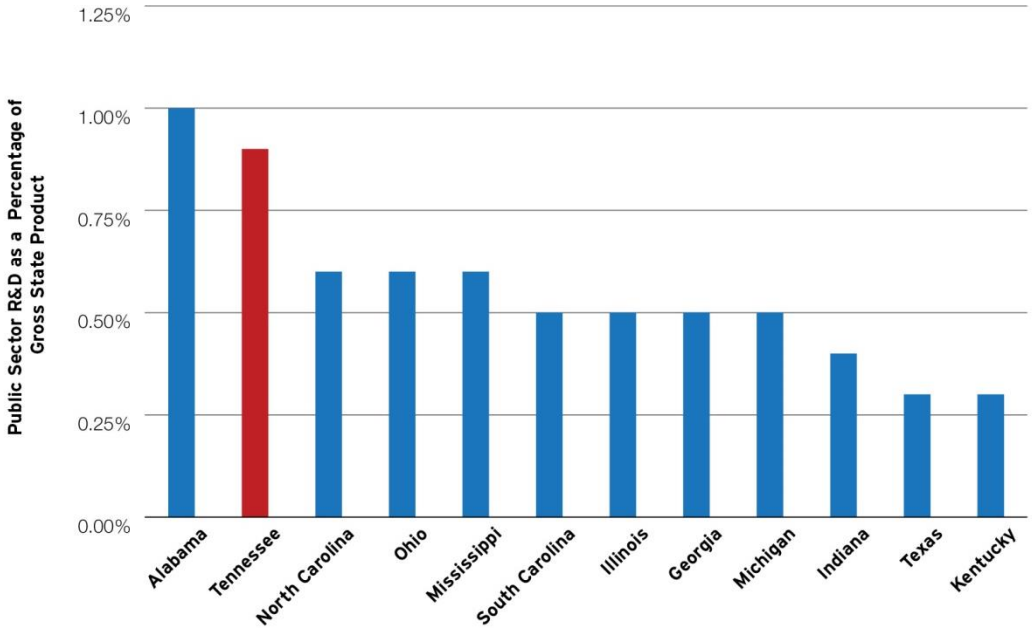
More recently, Tennessee has embarked on key reforms in its educational system. Passage of the Complete College Tennessee Act in 2010 set a new public agenda for higher education that directly links the state's economic development

plan with its educational system. This agenda seeks to increase educational attainment in the state, implements an exclusively outcomes-based funding formula for community colleges and TCATs as well as public colleges and universities, and aims to strengthen the connections between postsecondary education and economic and workforce development.[21] The recently announced "Drive to 55" initiative complements the Complete College Tennessee Act's efforts by setting a goal that 55 percent of Tennessee residents will have an associate degree or higher by 2025.[22] In addition, in 2012, Tennessee joined the Pathways to Prosperity Network, a collaborative effort headed up by Jobs for the Future and the Harvard Graduate School of Education that seeks to build career pathways linking high school and two-year postsecondary education programs in key industries, including advanced manufacturing.[23]

Meanwhile, the state's network of 27 Tennessee Colleges of Applied Technology has received recognition for providing solid occupational skills training in a variety of fields, including manufacturing, health care, and information technology.[24] The TCATs have a high completion rate (70 percent in 2009) and an impressive 83 percent job placement rate.[25] Likewise, several Tennessee postsecondary schools participate in the multistate Automotive Manufacturing Technical Education Collaborative (AMTEC) initiative, including Pellissippi State Technical Community College, Chattanooga State Community College, and TCATs in Murfreesboro and Shelbyville. Employers taking part in AMTEC partnerships include Aisin Automotive Casting, DENSO, Nissan, and Volkswagen.[26]

Lastly, with regard to innovation and technology development, the state possesses a number of **nationally significant technology development assets** of growing importance. Most notably, Tennessee boasts a formidable public research enterprise that ranks second among peer states and in the top 10 among all states for flows of non-industry R&D as a percentage of gross state product (GSP) funding to both federal, state, non-profit, and university research institutions.[27] Anchored by the University of Tennessee system (UT), Vanderbilt University, St. Jude Children's Research Hospital, and Oak Ridge National Laboratory (ORNL), this enterprise is beginning to cultivate significant commercial activity, particularly in the health IT and life sciences sectors.

In terms of public-sector R&D as a percentage of gross state product, Tennessee outperforms all but one automotive peer state



Source: National Science Foundation, 2013 Science and Engineering Indicators

The recently established LaunchTN initiative seeks to build on these assets by promoting the growth of high-tech startups in Tennessee through improved access to capital, technology transfer opportunities, and commercialization support. LaunchTN currently runs nine technology accelerators and has particularly strong competencies in the areas of IT, medical devices, and biotechnology. In 2013 LaunchTN moved to engage the auto industry by launching the autoXLR8R, a 13-week mentor-driven "boot camp" based in Tullahoma aimed at identifying, commercializing, and funding high-potential technologies and business concepts applicable to the industry.[28] To date, LaunchTN has provided nearly $7 million in seed funding to Tennessee startups and helped Tennessee businesses secure federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants by providing educational, training, and grant-writing support.[29]

Taken together, Tennessee possesses strong assets that make it an attractive place for the auto industry and other advanced industries to flourish.

Tennessee auto sector competitiveness SWOT summary

Strengths	Weaknesses
• Central location and strong transportation network with good access to the entire North American market • Low costs of doing business generally and for manufacturing specifically • Sizeable advanced industries base and significant recent momentum • Steady in-migration of skilled workers • Business-friendly stance in state government • Strong regional actors and a regionally-focused approach to economic development emanating from the Governor's office • Emergent efforts to bolster global engagement and international trade • Pieces of a robust, industry-relevant workforce and educational training system • Sizable innovation assets and federal R&D presence	• Low rankings on tax competitiveness for new R&D firms and labor-intensive manufacturing • Economic development stance underemphasizes automotive supply chain and local industry clusters • Position as an exporter and center for FDI could be improved • Low rankings on literacy, numeracy, and educational attainment • Variable quality of education and training programs that seek to respond to workforce needs of auto and other AI employers • Paucity of private-sector R&D and public R&D relevant to automotive subjects • Lack of rich technology linkages, networks, and exchanges and absence of a supportive technology development and commercialization process for auto-sector suppliers, particularly medium-sized firms
Opportunities	**Threats**
• Tennessee emerges as a global hub for automotive production as it complements its continued business-friendliness and cost advantages with an stepped-up focus on groups of firms including SMEs; improved supply chain synergies and cluster dynamics; and increased global connection • Tennessee develops the South's most dynamic and responsive workforce training system, capitalizing on performance-managed "bottom-up" problem-solving, region by region • Tennessee becomes a leading center of automotive process and product innovation by pairing strategic investments in AI technology capacity with a profusion of forums for tech transfer and technology exchange	• The state—electing to compete solely on cost factors against new low-cost entrants—drifts onto a lower-level tier in the industry and begins to lose market share in a global race to the bottom • Production sites in the state lose competitiveness as productivity gains plateau given industry's inability to field a nimble, high-quality workforce • Without hard-to-replicate knowledge or special process or product advantages the state remains stuck in a lower-value production niche and fails to move up the value chain

Yet Tennessee faces a number of deficiencies that could hamper the momentum of its automotive economy

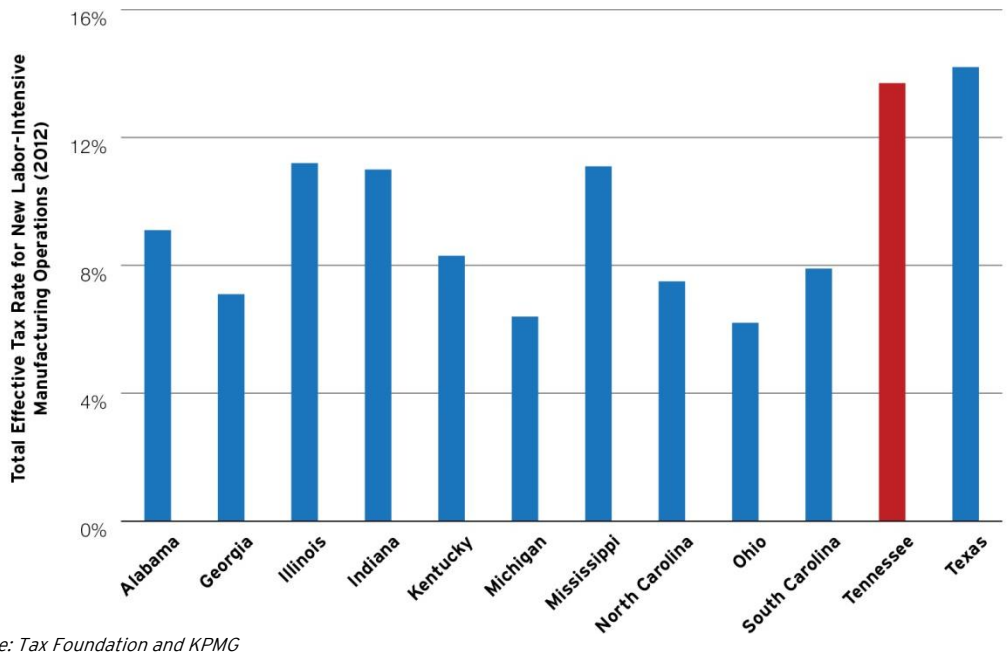
In this regard, at least three distinct challenges raise questions about the competitive prospects of the Tennessee auto sector as it negotiates an era in which cost factors are increasingly bound up with productivity factors, the availability of skilled workers, and technology deployment. These potential deficits could undercut the state's ability to compete and win in the next decade.

Elements of private- and public-sector strategy represent missed opportunities for industry growth

The first concern about the state's future readiness to compete involves its general business- and industrial-development stance. By and large Tennessee industry and government work well together to maintain an extremely competitive environment for private-sector firms.[30] However, establishing and maintaining a business-friendly environment for advanced industries such as the auto industry requires a lean and strategic development stance. Today, the state is surely lean but on a number of points lacks a truly strategic approach. Key areas in need of work include tax policy, the state's overall development ethos and priorities, and its international activities and policies.

Business taxes, for example, are a point of pride for Tennesseans. Given that the state ranks well on a number of state tax rankings, that pride is well founded.[31] And yet, with the state increasingly reliant on high-wage, high-value-added advanced

Despite Tennessee's low-cost reputation, the state places a comparatively high tax burden on young and labor-intensive manufacturers



Source: Tax Foundation and KPMG

industries like the auto sector, certain areas of the tax code suited to administering the state's traditional locally traded, consumer-serving businesses may be becoming problematic.

In fact, it may surprise Tennesseans to learn that despite their state's overall favorable ranking on tax competitiveness, Tennessee resides in the bottom fifth of states, according to the Tax Foundation, in terms of its tax competitiveness for new R&D firms and labor-intensive manufacturing.[32]

For example, the state currently provides no R&D tax credit, although 33 states do, including nine of the state's 11 auto-industry peers.[33] This is suboptimal, since such credits have been shown to stimulate private-sector R&D investment and help locations move up the technology development value chain.[34] Similarly, that Tennessee in 2011 maintained the highest state and local sales tax rate (9.43 percent) may impose another drag on economic growth. To be sure, while manufacturers are largely shielded from this uncompetitive burden by smart exemptions for business-to-business sales of machinery and other inputs, some auto suppliers contend that flow-through of the sales tax still hampers the business environment. For example, because businesses' purchases of custom software and utilities are not exempt, auto and parts companies must pay taxes on those inputs.[35] And then there have been concerns about the state's unemployment insurance (UI) taxes, which until this fall appeared to disproportionately hit young manufacturers. That problem is being resolved for now but the underlying issue remains—that the state is one of only a few states that continues to rely on industry-specific tax rates that perversely hit struggling industries hardest in setting the UI levy.[36]

The second area of concern regarding the business environment pertains to the state's overall business-government development stance, which tends to underemphasize the importance of collaboration among groups of firms within the state's automotive supply chain and local industry clusters. For their part firms in the industry tend to operate in a relentlessly cost-oriented economy through "arms-length," procurement-oriented relationships. This approach leaves little opportunity for beneficial coordination on problem solving, product and process quality, workforce development, or technology upgrades. Similarly, the state's overall economic development stance has been understandably focused on the recruitment and support of a few crucial OEMs, which in turn has motivated a strong emphasis on the attraction and support of *individual* larger firms rather than the development of groups of firms in the critical supply chain. As a result, the state may be missing opportunities to catalyze growth by working effectively in bulk across its auto supply chains and fostering the regional clusters into which they are organized.

For one thing, there seems to be an underappreciation of the importance of the supply chain in the state's economic development thinking. Despite the fact that suppliers encompass nearly 500 establishments and more than six times the employment of the OEMs, supplier-oriented economic development strategies remain thin and secondary. The state lacks, for example, a truly effective statewide automotive industry association and instead makes do with an inadequately resourced labor of love—the Tennessee Automotive Manufacturers Association (TAMA). Meanwhile, the state's business development energies and financial commitments to the auto industry remain heavily preoccupied with the recruitment of OEMs and responses to OEM requests. As a result, the hundreds of Tennessee suppliers that specialize in any number of the 2,000 components that go into the modern car remain somewhat ignored, which seems unwise given that the sheer size and diversity of the supplier network suggest it may well represent the lion's share of the state's growth potential in the auto economy.

This raises another shortcoming of the state's economic development stance: the state's relative lack of tailored attention to the needs of Tennessee's regional industry clusters—those complex networks of OEMs, suppliers, and supporting institutions that comprise the state's auto economy. Given the reliance of advanced industry OEMs and suppliers on intricate "co-location synergies," advanced industry states have an abiding interest in aiding and abetting the growth of their regional industry networks.[37] In this respect, properly designed regional cluster and supply-chain strategies represent a low-cost way to encourage adaptation and adoption of best practices, facilitate problem solving, and accelerate technology diffusion and innovation by helping to link and align the many factors that influence firm growth and regional economic strength.[38] On this front Tennessee has begun to recognize the clustered, regional nature of its industries' supply chains by decentralizing its economic development activities, as with the Jobs4TN program. However, as one industry leader noted, "there is a difference between decentralization and cluster development." So far the state's decentralization efforts have not yielded deep engagement with the state's existing auto clusters. In this regard, the state appears to be missing opportunities to catalyze growth by working effectively with its automotive supply chain clusters.

An additional area of concern regarding the competitiveness of the Tennessee business climate is the state's relationship to foreign markets. Tennessee's auto sector is, as Chapter III demonstrated, an emphatically global enterprise, with foreign firms owning one-sixth of the state's automotive establishments and employing just shy of half of the state's auto workforce. But Tennessee's early lead in winning FDI into the U.S. automotive industry has shrunk: more foreign-owned establishments can be found in Kentucky today than in Tennessee, and a greater share of establishments are foreign-owned in Alabama, Kentucky, South Carolina, and even Michigan. While this number also reflects Tennessee's greater success in building a presence in U.S. companies' supply chains, it points to the fact that much FDI is still pouring into the country that Tennessee is not capturing. And with only one in 10 Tennessee suppliers self-identifying as exporters, considerable room exists for the state to boost exports in the industry. Foreign-owned firms tend to be oriented toward producing for the domestic market, but in an era of global supply chains and continental production platforms, even they should be targets for export opportunities.

In this regard, the state has made important strides on global engagement, embodied in ECD's new international strategy and its appointment of an assistant commissioner for international affairs. However, the state's position as a home for exporters and a center for foreign direct investment could be improved. The most obvious deficit for the industry—albeit one that the state cannot erase—is the growing terms-of-trade competitive disadvantage that has resulted from the nation's slow progress in forging trade agreements with key export markets at the federal level. Currently, the United States simply lacks the broad access to major global markets enjoyed by some of its competitors.[39] As a case in point, Mexico—an increasingly formidable competitor for auto assembly—enjoys far greater access to major global auto markets because of its many trade agreements. At present, Mexico is a signatory to 12 trade agreements that cover 44 countries including Brazil, Japan, and the European Union, while the United States has agreements with just 20 countries. Conspicuously lacking from the U.S. list are agreements with Japan, the European Union, and Brazil. Because of the United States' limited number of trade agreements, added tariffs mean that an automobile exported from Tennessee to Brazil costs 55 percent more than one exported from Mexico.[40] Given these realities, the state should be extremely concerned about the recent lack of progress on the U.S.-E.U. free trade agreement negotiations, which also offer an opportunity for streamlining auto-safety standards.[41]

Beyond access to foreign markets, the state has until recently lacked clear strategies for assisting Tennessee automotive firms—domestic or foreign—in their efforts to export. Given that relatively few of Tennessee auto establishments currently export, increasing export levels for a number of export-ready firms at all tiers of the supply chain may be low-hanging fruit. To this end, the establishment of the TNTrade initiative represents an important step forward and reflects serious thought about the strategic development of Tennessee exporters as the federal State Trade and Export Promotion (STEP) program—which has funded Tennessee's efforts during the last two years—sunsets. However, while it remains too early to assess implementation of the international strategy that ECD published in May 2013, it appears the plan may rely too heavily on unilateral state actions and too little on partnerships with existing business development organizations and high-capacity partners at the regional level.[42] In this connection, local chambers of commerce, which already regularly perform business retention calls and have strong relationships with firms in their regions, should be an integral part of the strategy. Without enlisting such partnerships, the state export plan may not reach far enough to have real impact and runs the risk of duplicating existing efforts. The same goes for the state's new FDI strategy. With 17 percent of the state's auto-industry establishments foreign-owned, more systematic outreach back to home countries through this network could give Tennessee an advantage in the competition to attract new capital investments in the industry. This is one argument for maintaining close links between the state's export and FDI activities, even though those have recently been separated administratively.

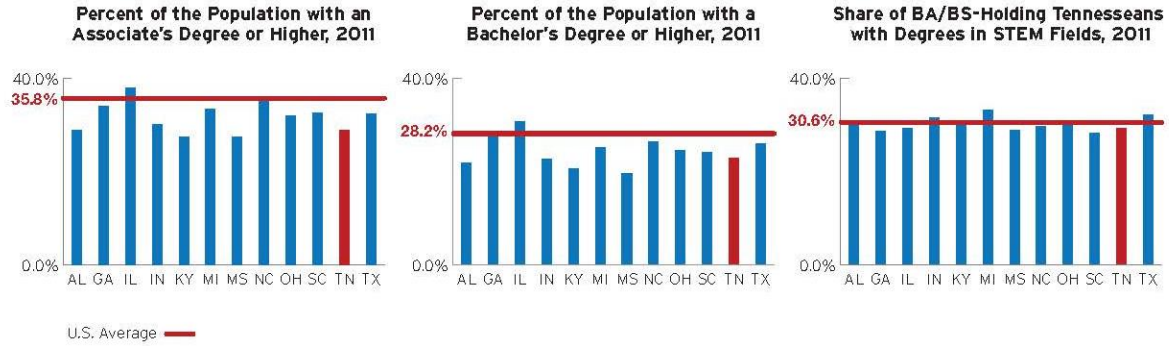
Marquee training partnerships with large employers mask uneven attention to SME needs and gaps in the workforce pipeline

While Tennessee is a leader on overall business friendliness, it faces significant challenges with regard to workforce development.

A number of impressive partnerships between employers, educational institutions, and training intermediaries demonstrate both sophistication and creativity. However, for all that the state has yet to assemble a cohesive, statewide system capable of meeting the changing needs of AI employers now and in the years ahead.

To begin with, Tennessee lags on literacy, numeracy, and educational attainment. Only recently has the basic education provided by the state's K-12 system become the object of real focus and investment. As a result, not only does the state rank close to the bottom among peer states and nationally for the share of adults with at least a two-year or a four-year college degree, but it performs no better on critical STEM-related education outcomes.[43] In 2011, Tennessee postsecondary institutions awarded 12,448 degrees and certificates in STEM-related fields of study—a figure that represented just 18 percent of total awards conferred and that ranked 41st nationally.[44] Of those Tennesseans with bachelor degrees, just 29 percent have degrees in STEM fields of study, ranking the state 36th nationally.[45] Figures like these complicate the state's efforts to ensure the availability of a sufficient and appropriately trained workforce for the auto industry.

Tennessee lags most peer states and the national average on measures of educational attainment



Source: Brookings Analysis of U.S. Census Bureau, American Community Survey

Turning to the specific workforce needs of the auto sector, a look at trends affecting worker availability and hiring suggests that the Tennessee auto-related labor market is experiencing significant stress as employers struggle to find and retain the employees they want even as some workers struggle to locate good jobs.

Identifying the skill needs of the auto—and AI—sectors

Identifying the skill needs of specific auto-related occupations poses a critical challenge for workforce development planning—and did for this analysis as well. In order to assess the auto industry labor market in Tennessee, Brookings used the Bureau of Labor Statistics' industry-occupation matrix to identify occupations with high levels of specialization in the auto industry as defined by NAICS codes 3361 (motor vehicle manufacturing), 3362 (motor vehicle body and trailer manufacturing), and 3363 (motor vehicle parts manufacturing).

Brookings then calculated occupational specializations to determine which occupations are disproportionately represented in the auto industry compared to other industries. Occupations with a score above one were considered to be auto-specialized. Brookings identified 60 auto-specialized occupations, which were sorted into three occupational

Identifying the skills needs (continued)

clusters: Production and Maintenance; Engineering and Design; and Managerial, Business, and Operations. (See Appendix D for the complete list of 60 auto-specialized occupations). These clusters, meant to be intuitive to both analysts and a general audience, are based on a number of factors including similarities in duties; job functions; the role in the organization; and the skills, education, and training needed to perform the work at a competent level. While the clusters are broad and cover an array of skills profiles and occupational activities, they serve to distill the data into three analytically useful categories.

It is worth noting that although workers in auto-specialized occupations are disproportionately represented in auto manufacturing, they also work in other industries. For example, other advanced industries in Tennessee employing workers in auto-specialized occupations include Household Appliance Manufacturing; Medical Equipment and Supplies Manufacturing; Electrical Equipment Manufacturing; Scientific Research and Development Services; and Management, Scientific and Technical Consulting. The Production and Maintenance cluster has the greatest number of workers in advanced industries other than auto (8,300 workers, or 6.5 percent of the cluster's workforce), while the Engineering and Design cluster has the highest share of workers in other advanced industries (22 percent, or 4,300 workers).

Such overlaps in worker skills requirements across industries hold important implications for workforce development planning in that some skills training programs can offer career pathways into a variety of industries.

To be sure, significant dispute surrounds the question of whether a "skills gap" or "worker shortage" exists. Manufacturing employers in Tennessee and across the nation persistently report difficulty in finding appropriately trained workers qualified to fill open positions.[46] Meanwhile, other voices argue against the idea of a skills gap and instead point—amid high unemployment rates—to low wages and limited industry investment in skills development as the cause of most labor market challenges.[47]

In addition, some Tennessee employers' use of temporary staffing services further complicates efforts to understand automotive labor market trends, particularly for production and maintenance workers, since these lower-skilled contract workers are not included in official counts of the manufacturing workforce.

With that said, it is safe to say that several significant dynamics are seriously complicating labor market transactions in Tennessee.

For one thing, the sharpening demands of the productivity imperative—which are driving changes in vehicle production processes and technologies—have been steadily altering the skillsets required by engineering and design as well as production and maintenance workers in the auto industry. Specifically, worker "upskilling" appears well underway and reflects the fact that the evolving automotive production system frequently calls for enhanced skill sets, including competence with a wider variety of tasks, increased comfort with technology, and greater flexibility to adapt to rapid process and technology change. For engineers and design workers upskilling may require increased adeptness at "systems thinking," training in multiple engineering disciplines including computer design and electronics, and the ability to work as a part of a team.[48] For workers in production and maintenance occupations the trend can require higher levels of literacy, numeracy, and communication skills as well as added familiarity with complex, computer-controlled machines.[49] In each case, upskilling may be complicating both firms' ability to locate appropriately skilled workers and workers' ability to prepare themselves for employment in a changing industry.

One indication that upskilling may be causing labor market strains can be found in Brookings' analysis of 2012 online job advertisements in Tennessee as aggregated by the Conference Board's Help Wanted OnLine data series. (See Appendix A for a full explanation of the Brookings methodology.) This analysis shows that most of the hard-to-fill occupations in the production and maintenance cluster call for some level of postsecondary education or moderate- to long-term on-the-job training, while the jobs least difficult to fill in this occupational cluster overwhelmingly require only a high school diploma.[50]

("Hard-to-fill" jobs are those re-posted at least once after the original posting, which suggests that employers need more time to find the right candidates.) What is more, online job postings suggest that jobs in some auto-specialized occupations are proving particularly hard to fill. For example, 47 percent of auto-specialized maintenance job openings (including positions such as industrial machinery mechanics and electronics repairers) are listed longer than one month, compared to 39 percent of all maintenance occupations, an indication that auto-manufacturing employers require additional time in order to find suitable workers.[51]

Tennessee employers struggle to fill positions across a variety of occupations in the automotive industry

Hard-to-Fill Production & Maintenance Occupations	Hard-to-Fill Engineering & Design Occupations	Hard-to-Fill Managerial, Business, & Operations Occupations
First-Line Supervisors, Production Workers	Industrial Engineers	Purchasing Agents
First-Line Supervisors, Mechanics & Installers	Mechanical Engineers	Production, Planning, & Expediting Clerks
Industrial Machinery Mechanics	Electrical Engineers	Architectural & Engineering Managers
Machinists	Operations Research Analysts	Purchasing Managers
Welders, Cutters, Solderers, & Brazers	Industrial Engineering Technicians	Logisticians
Computer-Controlled Machine Tool Operators	Health & Safety Engineers	Industrial Production Managers
Tool & Die Makers	Engineers, All Other	Occupational Health & Safety Specialists
Industrial Electrical Repairers	Mechanical Drafters	
CNC Machine Tool Programmers	Materials Engineers	
Model Makers, Metal & Plastic	Electro-Mechanical Technicians	
	Commercial & Industrial Designers	

Source: Brookings analysis of data from BLS Occupation Employment Statistics, BLS Industry Occupation Matrix, and the Conference Board's Help Wanted OnLine database

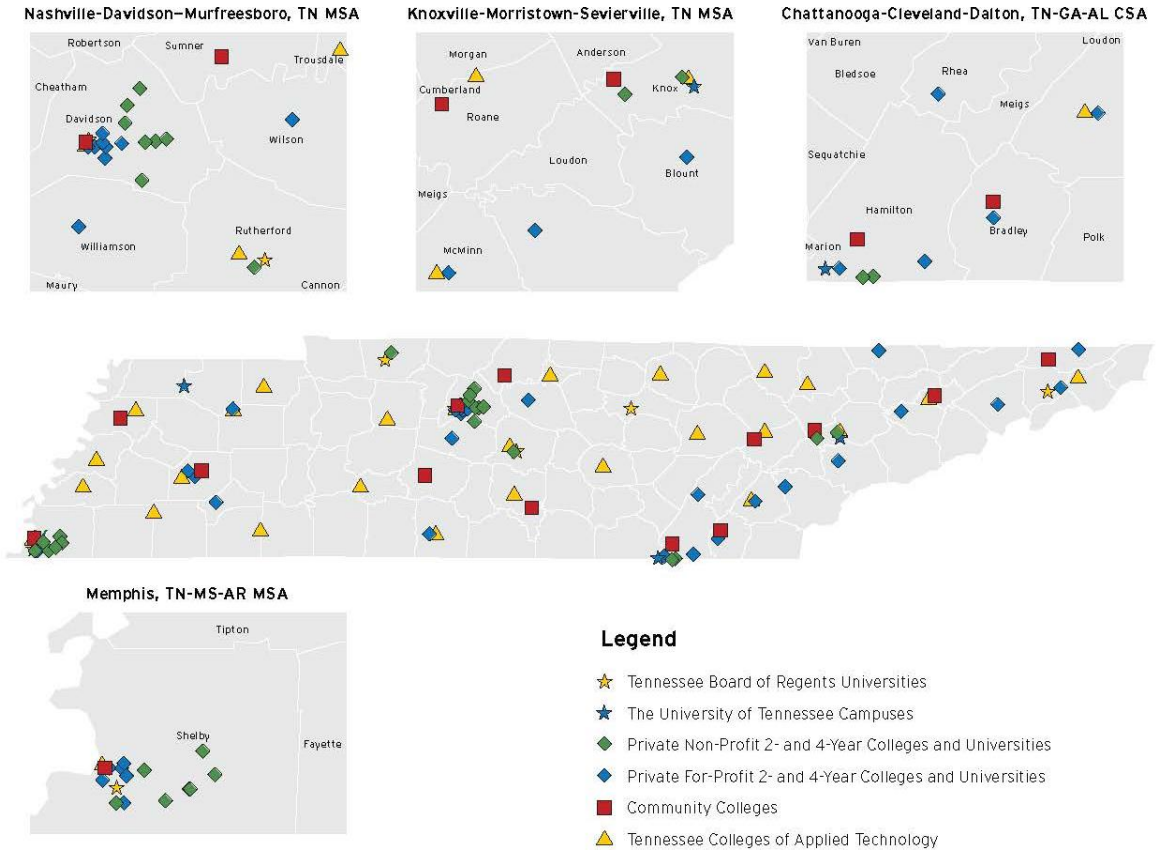
At the same time, several other cross-cutting dynamics may also be complicating matters in the automotive labor market. For one thing, employers' expressed difficulty in finding and retaining workers with the skills and experience they desire almost certainly is being influenced by the fact that the auto industry currently faces accelerating retirement rates due to a rapidly aging workforce. Southern workers in the production and maintenance and engineering and design occupational clusters are all older than the average U.S. worker, with just 20 percent of such workers under age 35 and roughly 60 percent between the ages of 35 and 55. By contrast, one-third of all workers in the United States are under the age of 35,

and 46 percent are between the ages of 35 and 55.[52] These demographic trends raise concerns about the impact of successive waves of retirements in the years ahead, especially in engineering and managerial occupations. Additionally, some employers' own practices may be hurting their ability to recruit, hire, and retain the workers they need. Regular use of temporary staffing workers can disrupt internal labor markets that would otherwise allow firms to "grow their own" workforce.[53] Likewise, a reliance on temporary workers may also reduce workers' commitment to their jobs, given that the contingent nature of their employment suggests that firms are not invested in their advancement. Lastly, for many positions employers' work experience prerequisites effectively require applicants to have already done the job in question before being hired to do it. Interviews with Tennessee employers reveal a widespread desire to hire experienced engineers and skilled trades workers rather than recent graduates.[54] Several employers asserted that the private sector should offer more internships and cooperative education opportunities in order to address this work experience catch-22: An individual cannot get a job without work experience and cannot get work experience without a job.

All of which is to say: Hiring in the Tennessee auto sector—as in other advanced industries—is complicated by the fact that the industry is in transition. Disputes about the state of the labor market, new skills needs, the persistence of negative views about manufacturing despite great change, new competitive realities limiting pay and training, a generally more risk-averse private sector that is reluctant to hire after weathering the Great Recession: All of these influence the pace and ease of hiring in the Tennessee auto industry and are tied to the enormous changes that the industry is undergoing.

And yet there is a third major challenge the state faces with regard to workforce development: the variable quality of the education and training programs seeking to respond to the worker needs of auto and other AI employers. In this connection,

Multiple systems and institutions train Tennessee's auto industry workforce



Source: Brookings analysis of the National Center for Education Statistics, Integrated Postsecondary Education Data System

a Brookings assessment of the state's training infrastructure suggests that the state possesses less a fully intentional and AI-focused workforce system than a set of cutting-edge, often state-supported one-off programs superimposed on top of a patchwork of regional initiatives of disparate quality.

Tennessee's basic training infrastructure is anchored by the state's 13 community colleges, 27 Tennessee Colleges of Applied Technology, and 10 public universities. Within this varied infrastructure operate numerous strong training programs at the local level that have high completion rates and meet employers' skills needs. These institutions offer dozens of programs that potentially feed into automobile manufacturing, including programs that range from welding to engineering. In 2011, for example, the TCATs awarded 2,500 certificates and diplomas in fields of study related to auto manufacturing, concentrated in mechanical and production-related fields such as welding, industrial maintenance, and machine tool technology. That same year the state's community colleges awarded an additional 1,200 auto-relevant certificates and degrees, with emphasis on business administration and engineering.[55] And for their part, Tennessee universities graduated 4,600 students in auto-related fields of study, including an array of subdisciplines within engineering and business administration.[56]

For all of this infrastructure, however, relatively little of it supports specific human capital development for the state's auto or AI sectors. To be sure, state schools do produce large numbers of degrees, certificates, and diplomas that potentially feed into auto manufacturing employment. However, relatively few of the state's education and training programs have strong ties to the automotive industry in particular or advanced industries in general. In this connection, the state's TCAT programs tend to be those most closely tied to particular occupations or industries, including auto manufacturing. However, community college and university programs tend to be broader in orientation, and auto-related courses of study focus predominantly on business and engineering, which can lead to a variety of occupations and industries beyond auto. As a result, the sum total of these activities cannot be said to add up to a truly effective, comprehensive workforce training system for Tennessee's advanced industries.

And yet there is another layer to the system. The Tennessee training ecosystem is dominated by a handful of large-scale, "one-off" programs that consume large infusions of public resources and attention yet serve only a small portion of the state's automotive workforce.

To be sure, these one-offs—mostly developed to serve major OEMs or tier 1 suppliers—are impressive. Among these marquee initiatives are Motlow State Community College's partnership with Bridgestone to provide associate degree programs in mechatronics and critical skills certifications in classrooms and labs located at the Bridgestone facility and Chattanooga State Community College's degree programs at the renowned Volkswagen Academy.[57] Likewise, a planned collaboration between TCAT Murfreesboro and Nissan will include a new 170,000-square-foot TCAT advanced manufacturing training center adjacent to the Nissan facility that will provide training for Nissan employees as well as a program in industrial electrical maintenance.[58] In each case, these model partnerships appear to be delivering state-of-the-art training to important portions of the state's industry.

And yet, the fact remains that the state's marquee training partnerships—no matter how cutting-edge—do not make for a state-of-the-art workforce development system. At best the signature training projects cater to a relatively small fraction of the state's industrial base. Even operating at full capacity, for example, the Bridgestone, Volkswagen, and Nissan initiatives would only meet a portion of the auto industry's needs in a few regions. Moreover, each of these three endeavors seeks to address the specific labor demands of a particular OEM or larger supplier (though only the Volkswagen Academy formally limits enrollment to VW trainees and employees). As such, these impressive initiatives remain somewhat separate from the state education and workforce development system.

Related to the state's heavy focus on OEM-related one-offs is its relative lack of focus on training for the rest of the industry. Specifically, the state's activism in organizing and/or funding marquee partnerships has not been matched by an equally energetic and systematic effort to meet the training and labor market needs of all auto employers, especially smaller suppliers (although it should be acknowledged that more than 50 automotive firms have received training dollars through ECD's FastTrack program during the last few years).

SME suppliers often lack well-developed human resources structures, internal training systems, and budgets for workforce skills training and face the additional challenge of losing employees to OEMs and larger firms that can offer better wages.[59] Furthermore, smaller companies are less able to devote resources such as staff time and equipment to forming robust partnerships with TCATs and community colleges and often have difficulty articulating the specific competencies they need. As a result, they must make do with the available local workforce system as it operates separately from the major marquee model efforts, and so they frequently struggle to hire and retain workers with the appropriate skills, creating chokepoints for the industry as a whole.

The implication of this current situation is that an absence of strong state leadership beyond the marquee projects has left the rest of the state's training organizations to respond in variable ways to the challenge of preparing the workers needed by the state's AI supply chains.

The TCATs and community colleges do possess a solid track record of responding effectively to the needs of their local labor markets within the boundaries of their service areas—often with support from the state. For example, when Magneti Marelli moved to Tennessee, the firm was able to work closely with the TCAT in Pulaski to develop a specific training course for Marelli employees on plastic injection molding.[60]

Meeting the automotive industry's training needs for hard-to-fill occupations implicates a broad range of institutions in the state

Top Degree-Conferring Institutions for Hard-to-Fill Production & Maintenance Occupations	Share of State Degrees in Field (2011)	Top Degree-Conferring Institutions in Hard-to-Fill Engineering & Design Occupations	Share of State Degrees in Field (2011)	Top Degree-Conferring Institutions in Hard-to-Fill Managerial, Business, & Operations Occupations	Share of State Degrees in Field (2011)
TCAT-Jackson	9.8%	The University of Tennessee at Knoxville	16.0%	The University of Tennessee at Knoxville	15.7%
TCAT-Morristown	7.8%	Tennessee Technological University	11.8%	Vanderbilt University	7.9%
TCAT-Dickson	5.7%	Vanderbilt University	9.4%	The University of Tennessee at Chattanooga	7.3%
TCAT-Shelbyville	5.2%	The University of Tennessee at Chattanooga	5.8%	Middle Tennessee State University	6.5%
TCAT-Memphis	4.7%	Middle Tennessee State University	5.2%	Tennessee Technological University	6.1%
TCAT-Crossville	4.3%	ITT Technical Institute-Knoxville	4.1%	University of Memphis	5.3%
TCAT-Knoxville	4.3%	Chattanooga State Community College	3.2%	Austin Peay State University	3.3%
TCAT-Harriman	4.0%	Austin Peay State University	2.9%	King College	3.1%
TCAT-Hartsville	3.7%	Nashville State Community College	2.8%	Bryan College-Dayton	3.1%
TCAT-McKenzie	3.7%	University of Memphis	2.7%	Tusculum College	2.9%

Source: Brookings analysis of the National Center for Education Statistics, Integrated Postsecondary Education Data System

Likewise, several other initiatives across the state are currently working to develop comprehensive approaches that bring together consortia of employers, educators, and workforce and economic development leaders to craft training solutions that are broader in scope than any one entity could accomplish individually. For example, the Middle Tennessee Skills Panels—an initiative of the Tennessee Board of Regents, the workforce boards, and higher educational institutions—pulls together groups of employers of all sizes with similar workforce challenges in three key industries (health care, information technology, and advanced manufacturing) to develop shared regional solutions that will benefit each industry as a whole.[61] For its part, the Regional Center for Advanced Manufacturing (RCAM) in Kingsport is working to cultivate a manufacturing workforce for the 21st century. This public-private partnership forged by Northeast State Community College, Eastman Chemical, Domtar, the city of Kingsport, the Kingsport Chamber of Commerce, and ECD (which has provided $15 million in funding since the center's inception) provides accredited courses in a variety of fields that can be applied toward completion of associate of applied science degrees as well as technical certificates. In addition to serving the over 400 students currently enrolled, RCAM also offers custom training for manufacturers in the region.[62]

However, the fact remains that these innovative "bottom-up" advances in the state's regions remain exceptions rather than the rule. By and large, employers and the educational institutions and workforce intermediaries in their regions are on their own—with relatively little support or guidance from the state—when it comes to devising training solutions.

In this respect, problem solving by front-line companies and training organizations in the state's regions has been complicated by the absence of state activism on workforce development direction setting and system building to match its focus on the signature one-offs. Few signals have been sent conveying the state's vision of good workforce development practice. Little guidance or motivation has been provided that would help TCATs and community colleges engage with area employers and respond to labor market conditions in optimal ways. And for that matter no organized structure exists to enable local leaders to share strategies that can be adopted and adapted by multiple regions and so begin to diffuse best practices throughout the state.

Most commonly, a school will work with a single employer to devise programming that meets a specific short-term training need. Only rarely do TCATs and community colleges have the incentive or resources to adopt a fully regional supply-chain approach to training for a whole industry or set of industries, particularly given the level of labor market analysis and industry outreach and organizing required to develop smart industrywide solutions. As a result, promising models like the Middle Tennessee Skills Panels and RCAM operate in isolation, innovation remains patchy, and many employers struggle to staff their production lines.

Thus, the state workforce development "system" is not really a system. Instead, it remains a highly variable patchwork of disparate individual solutions worked out between large firms and the state or region to the best of local leaders' abilities.

Limited technology transfer and private R&D activity constrain the state's innovation system

Finally, the state's innovation system stands in need of improvement. Currently, the state technology development system is anchored by substantial publically supported R&D activity, led by robust and growing federal and university investments in Oak Ridge National Laboratory, the University of Tennessee, Vanderbilt University, and other research institutions. This provides the state an important base for cultivating a technology edge over the long term.

However, notwithstanding the enviable scale of that public-sector base, a number of deficiencies in the state's innovation and technology development enterprise limit tech-oriented commercial activity in the auto sector.

To begin with, the state's public R&D activity—while robust in general—appears weaker and more nascent when it comes to auto-industry-related technology development.

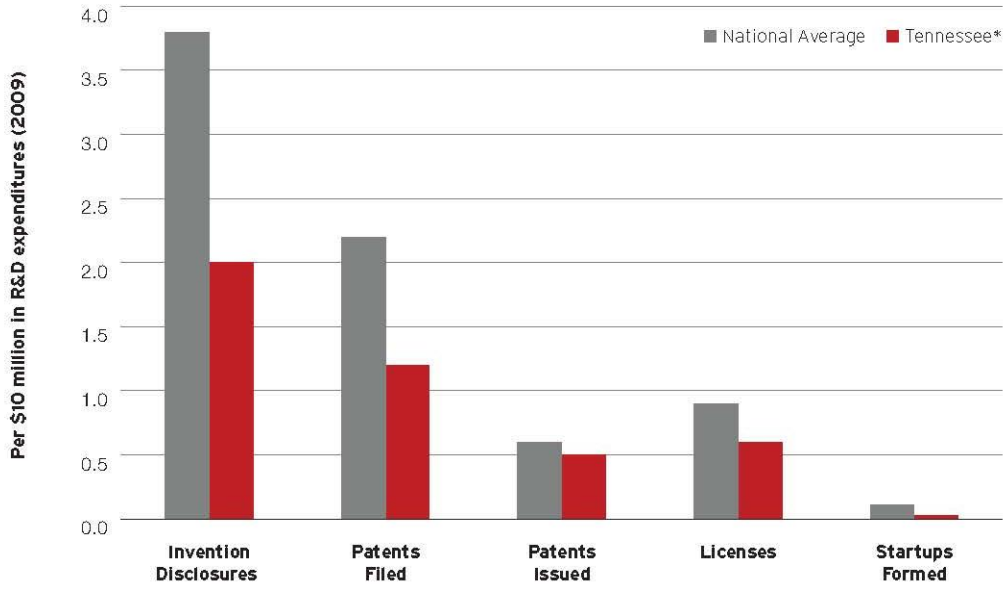
Among Tennessee's research universities, there is little focus on the basic or applied sciences that most directly affect the auto industry (such as advanced composites, computation, and the intersection between mechanical and electrical engineering). The vast majority of Vanderbilt's R&D expenditures occur within biotechnology, health IT, and medical devices,

and although UT has some noteworthy investment plans for material science, the university has few explicit connections to the auto industry. For example, more than two-thirds of UT's federal funding comes from the Departments of Defense and Health and Human Services and the National Science Foundation—agencies with research agendas not traditionally aligned with the auto industry. In a similar vein, only 3.5 percent of UT's engineering department's R&D funding comes from the auto industry.[63] A similar tilt can be discerned in the important Governor's Chairs program, which supports high-level faculty appointments in applied research disciplines at UT and ORNL. Of the 11 current chairs, only two work in areas relevant to the auto industry (fuel cells and material science), although recently a third expert in additive manufacturing has been appointed.[64] Finally, UT's Center for Transportation Research is focused on the right topic but is currently in its very early stages and is more of an educational center than a research-generating institution.

Secondly, Tennessee seems to struggle with generating research that is directly related to commercialization efforts—both in general and specifically in the automotive domain. Across all disciplines, Tennessee's two largest universities, Vanderbilt University and the University of Tennessee, which together represented 98 percent of patents produced by Tennessee institutions of higher education in 2010, rank 89th and 93rd respectively among U.S. research universities for the number of patents generated as a share of research expenditure. Relatedly, the universities' associated licensing revenue amounted to only 1.3 percent of research expenditure in 2010, placing Tennessee sixth among its peer states. Furthermore, only 29 of the 141 open licenses granted by Tennessee public research facilities in 2009 went to Tennessee-based companies—suggesting a thin level of engagement among Tennessee firms with regard to high-tech growth.[65]

Finally, while both Vanderbilt and the University of Tennessee have emphasized the importance of technology transfer and spin-off businesses in recent years, neither has developed a formidable tech-transfer operation. While Vanderbilt has made substantial inroads in penetrating the medical device and life science industries, few technologies are supporting the

In 2009, Tennessee's research-performing institutions lagged the national average on a variety of technology transfer metrics



** Includes University of Tennessee, Vanderbilt University, Oak Ridge National Laboratory, St. Jude Children's Hospital, Tennessee Regency System, and Y-12 National Security Complex*

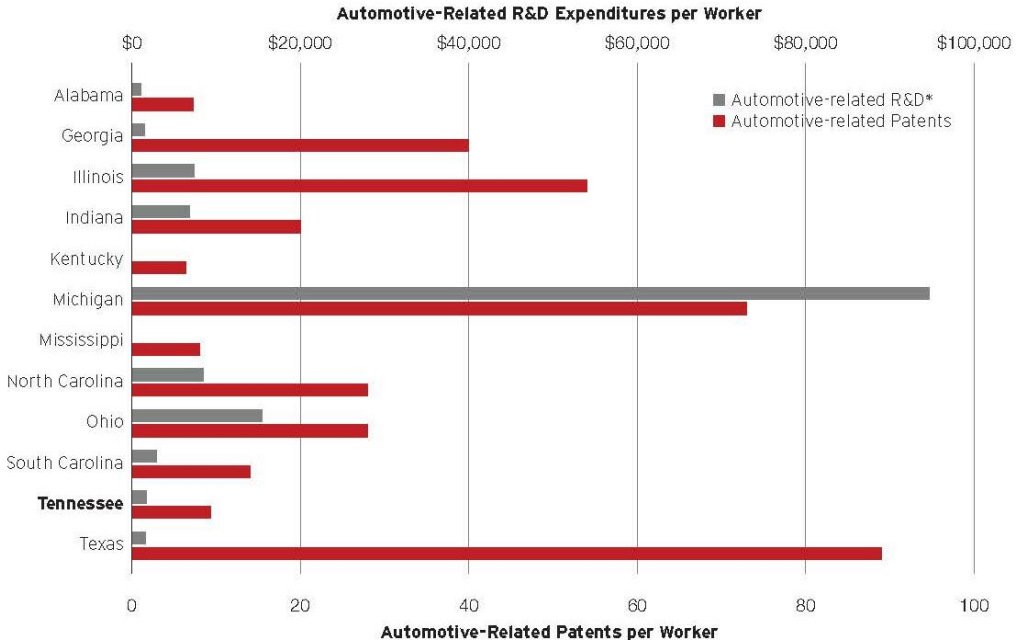
Source: Adapted from Battelle's Technology Partnership Practice, 2011

automotive industry. For its part, UT has increased the number of full-time licensing employees from three in 2010 to six in 2013. Nonetheless, UT still falls behind other leading public universities in terms of actual licensing agreements. As to the actual spin-off or spin-out of new firms, it does not happen regularly enough. According to data from Battelle's Technology Partnership Practice, the number of startups emerging from Tennessee research institutions as a percentage of research expenditures is one-third the national average.[66]

More distressingly, the tech-transfer situation may actually be worse when it comes to auto-related technologies. Of UT's corporate R&D interactions (including tech transfer, R&D awards and grants, and the like), only a handful involve the auto industry. Likewise, of the 32 startups associated with UT over the last 10 years, none were in the auto industry.[67] Vanderbilt University has also effected little tech transfer to the auto industry. Of the 354 technologies available for transfer, none are directly applicable to auto design, testing, or composition.[68] More broadly, virtually all of the private-sector interactions at both institutions involve large multinational OEMs or tier 1 suppliers rather than firms further down the supply chain, which could also benefit from such engagements.

This raises a related but different challenge for Tennessee: the paucity of private-sector technology development being undertaken by Tennessee firms. Strong innovation systems demand strong private-sector involvement and leadership. Nationally, two-thirds of R&D is performed by the private sector, which tends to provide the shortest pathway to commercialization. R&D in Tennessee, however, is heavily oriented toward federal and university activity, with relatively little private-sector involvement. In this regard, Tennessee is just one of two auto-industry peer states (Mississippi is the other) in which the private sector carries out less R&D than the public sector.[69] What is more, this alignment reflects a decade-long decline in the private-sector share of R&D expenditure in the state: Prior to 2005 Tennessee maintained more private R&D investments than public. However, since that time private investment has declined to 41 percent of total research expenditures in the state.

Given its workforce size, Tennessee's automotive industry underperforms in patenting and R&D



** Figures not available for Kentucky and Mississippi*

Source: National Science Foundation; Harvard Institute for Strategy and Competitiveness

The state's paucity of private-sector R&D is particularly pronounced in the auto industry. Even companies with headquarters operations in Tennessee typically elect to locate their R&D operations elsewhere, often in Michigan or California. In any event, the Tennessee auto industry performs just over half as much R&D per worker as in Southern peer states, confirming that the state largely remains a production and assembly site.[70] Undersized private-sector R&D within the state, moreover, has translated into weak patenting among firms in Tennessee's auto industry. Currently Tennessee ranks 47th nationally for the number of patents approved within the auto industry per 1,000 employees.

And yet imbalances in the mix of the state's R&D flows—and shortcomings in technology transfer—are only part of the challenge facing the state. Also of concern is a shortage of strong efforts to facilitate collaborative technology development throughout the Tennessee auto supply chain. This matters because, according to the Center for Automotive Research, 25 to 40 percent of R&D within the auto industry is now undertaken by suppliers. However, too little has been done in Tennessee to catalyze, facilitate, and support technology development, deployment, and commercialization among high-value suppliers, especially medium-sized ones.[71] As a result, the state may be leaving untapped some of its best prospects for developing a serious auto-sector technology presence.

Along these lines, the state seems to lack both rich technology linkages, networks, and exchanges and a supportive technology development and commercialization process for auto-sector suppliers, particularly those of medium size.

To the first point, the presence of over 160 medium-sized automotive establishments (those with between 100 and 500 employees) in Tennessee underscores the importance of focusing the state's innovation system on a subset of "innovation-ready" firms.[72] These medium-sized establishments—almost half of which are either mid-sized company headquarters or single-location firms, as opposed to branch plants of larger companies—represent the "missing middle" of the Tennessee innovation ecosystem. Such firms are large enough to value technology licensing and turn it into growth but are not large enough to have in-house legal or R&D support staff to help them seek out technologies and navigate the licensing process. These are the firms that could most benefit from modest public or private efforts to support their technology development efforts.

However, these firms currently lack regular forums, convenings, or networks through which to interact with one another and the state's public-sector R&D centers. A case in point is Oak Ridge National Laboratory, which represents over 40 percent of Tennessee's total R&D. Oak Ridge maintains a number of core technology and process competencies relevant to the auto industry, including materials science (particularly carbon fiber), electronics, and battery storage.[73] It has also experimented with efforts to make its technology more accessible to Tennessee firms, as with its annual "Bridging the Gap" convening that showcases ORNL's technologies and capabilities to firms and external research organizations.[74] Yet, with the exception of the ORNL Carbon Fiber Consortium, which connects a number of Tennessee firms to large international firms, few Tennessee suppliers enjoy strong ongoing linkages to the lab.[75] Of the approximately 1,100 current external users of ORNL technologies (either through user agreements, licensing, or cooperative R&D) only a small fraction are within the state and only one of the eight Technology Assistance Program partners at ORNL—Top Five, Inc.—is an auto supplier with a location in Tennessee. In part this likely owes to a number of inflexible lab-system rules and practices that have been increasingly recognized as major deterrents to effective lab-to-market tech transfer.[76] However, according to Top Five, Inc. President Jeff McCay, "there is also an education disconnect, where Tennessee suppliers simply are not informed of the opportunities that exist to coordinate with the ORNL or any of the other public research institutions."[77] Nor is ORNL unique. Neither the relevant UT departments nor the state's other research facilities appear to maintain significant networking forums for auto suppliers. For example, although Vanderbilt University offers a number of informal opportunities for university researchers to interact with biotechnology firms, nothing analogous exists for the auto industry. In short, the state lacks sufficient numbers of vibrant technology development networks and public-private collaborations aimed at enhancing the state's technology base.

At the same time, the state's own more formal technology development programs remain somewhat ill-suited to addressing the specific technology issues of the auto industry. After all, Tennessee's advanced industries include the life sciences and IT as well as auto parts, and while this diversity points to rich potential for growth, it has complicated policy design. Most notably, although LaunchTN—the state's primary growth support program for innovative companies—has established an impressive track record in its short tenure, it appears more oriented toward the needs of IT, consumer Internet, and medical

electronics startups. Startups and rapidly growing companies in these industries often have substantial seed funding needs but are able to scale quickly due to relatively short production timelines with limited marginal costs. By contrast, advanced manufacturing firms—particularly in the auto sector—have longer lead times, grow in stages related to contracts, and demand patient capital and frequent engagements with technology support programs.

Consequently, LaunchTN—while an essential initiative for the state—has not as yet demonstrated its relevance for advancing innovation and growth among small and medium-sized automotive firms. Evidence of this emerges from its initial fundings. LaunchTN's 2012 Technology Maturation Fund financed firms in the health care, consumer Internet services, defense, cleantech, and biotechnology fields.[78] No auto firms received funding. With that said, LaunchTN has this year piloted at least one potentially helpful technology development model for the auto sector: the autoXLR8R—a 13-week accelerator program for auto-sector startups. Based at the South Middle Tennessee Entrepreneur Center (SMTEC) in Tullahoma, the program's highly relevant mission is to identify, commercialize, and fund promising new technologies applicable to the automotive industry. As with all accelerators, the question will be whether the program can leverage Tennessee's core competencies and regional industry clusters to grow the state's auto industry and expand its innovative capabilities. As yet it is too early to judge.[79]

So for now the main takeaway must be that LaunchTN may be missing important opportunities to support Tennessee's auto suppliers due to its current program mix and finance model. Whereas automotive parts suppliers need capital over a relatively long period for advanced machinery, training, and scaling to meet purchasers' needs, LaunchTN is mostly oriented to an IT/consumer Internet startup model focused more on quickly linking suppliers to venture capital funding or helping with SBIR applications and then parting ways.

In sum, the Tennessee auto industry is presently in a unique position. While overall robust funding of the state's public R&D enterprise would seem to offer opportunities for technology adoption and deployment, shortages of auto-focused R&D, a lack of private R&D, and a dearth of formal and informal mechanisms for technology transfer—particularly those that could support suppliers' needs to stay current on technology—have kept the industry disconnected from Tennessee's innovation assets.

* * *

In short, Tennessee enjoys a strong position in the North American auto production sector but contends with several deficits as it moves into an era in which advantage will need to be won not just by dint of cost factors but also through world-beating productivity, human capital, and innovation capacity. Attacking these deficits will furnish the outlines of a strategic agenda for advancing the Tennessee auto sector in the decade ahead.

Select State-Level Initiatives

State	Description
Drive Continuous Industry Development	
Maryland	Maryland's governor-appointed Director of Cyber Development coordinates the state's efforts to bolster the strength of its cybersecurity industry.
Michigan	Pure Michigan Business Connect is a multibillion-dollar public-private partnership that supports growth in Michigan manufacturing supply chains by connecting firms to procurement resources and business assistance support through a business-to-business network.
Florida	In 1991 the Florida state legislature provided seed funding for the creation of the Technology Coast Manufacturing and Engineering Network, which supports multi-firm collaborations that strengthen and expand the Okaloosa County defense and aerospace supply chain.
Washington	Washington State's Export Washington portal provides companies a one-stop shop for the tools and assistance needed to grow exports by guiding companies through building an export plan, finding funding, consulting with specialists, and getting connected with contacts overseas.
Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base	
Kansas	The Director of Workforce Training and Education Services, a liaison position shared by the Kansas Department of Commerce and the Kansas Board of Regents, supports greater coordination of state workforce development and economic development efforts by Commerce, the Board of Regents, the KANSASWORKS State Board, the state's Postsecondary Technical Education Authority, and WIA-related programs.
Kentucky	Kentucky's Workforce Investment Board adopted a sector framework to guide its workforce investments and align those investments with the state's economic development priorities. Part of this effort involved the creation of a Sector Strategy Toolkit to assist local and regional actors in developing effective sector strategies.
Maryland	EARN Maryland is a competitive grant program designed to support regional, industry-led partnerships that coordinate workforce development, economic development, and education efforts.
Washington	Established in 2000, Washington State's Industry Skill Panels bring together key stakeholders from the worlds of business, education, labor, and workforce development to identify and address skills needs in key industries throughout the state.
Commit to Innovation at All Levels of the Supply Chain	
Connecticut	Connecticut's Innovation Vouchers program provides unmatched grants of up to $10,000 to early-stage, "growth ready" firms for the purchase of innovation services from universities, labs, or private firms.
Nebraska	The Nebraska Advantage R&D Tax Credit was recently extended to cover R&D projects that last up to 21 years. The credit allows firms to take a state tax credit on R&D expenditures equal to 15 percent of the federal R&D credit (35 percent of the federal credit for research expenditures at a Nebraska university).
Ohio	InvestOhio Program provides a 10 percent tax credit to firms or individuals that invest up to $10 million in Ohio small businesses, the program as generated $700 million in investment in the two years since its inception.
Virginia	The Commonwealth Center for Advanced Manufacturing, created in 2011, focuses on supporting innovation in the aerospace industry while advancing the research efforts of Virginia's university system. It emphasizes the acceleration of basic research into technologies that can be applied in a diverse range of industry sectors including aerospace.

VI. TENNESSEE'S AUTO INDUSTRY FUTURE: A VISION AND STRATEGIES FOR GETTING THERE

Tennessee has emerged as a Southern automotive powerhouse. The state's original underlying strengths—a strategic, low-cost location equipped with excellent transportation infrastructure—have been enhanced in the last decade. Today they position Tennessee well in the face of a number of disruptive megatrends that are greatly altering the global industry.

In this regard, the state's prospects are in fact bright despite growing domestic and international competition—*if* the state moves to prepare itself for an era in which the winning firms and states will be those that combine competitive cost factors with workforce and technology excellence.

Tennessee, along these lines, has worked hard to maintain its nationally recognized standing as a business-friendly environment for automakers and suppliers even as it has built up a dense, multidimensional supplier network.

Likewise, the state has begun the work of improving its education system while launching several national models of high-quality workforce training.

And discussion has begun about how the state can leverage a number of indisputable innovation assets in order to deepen its competitiveness in critical technologies such as carbon fiber and other composites as well as emerging technologies such as advanced internal combustion engines and fuel cell batteries. These technologies are essentially opportunities for the supply chain to "future proof" itself against a number of sweeping transformations that will affect the global automotive market.

All of which is to say that Tennessee has begun the work of updating its market appeal but now needs to go farther if it wants to strengthen and advance its position in the forefront of the automotive industry. Specifically, the state should

commit itself to a bold vision in which **Tennessee emerges as a premier global destination for high-value automotive production** in the next five to 10 years.

As to what the fulfillment of this vision might look like, the next phase of auto industry development could (with concerted effort) see Tennessee emerge as:

- **A global hub for automotive production and vibrant supplier networks** known for remarkable synergies and efficiencies offered by the constant interactions of its automakers, SMEs, industry associations, educational organizations, and state and local government. In this future, additional OEMs are increasingly attracted to the state for the same reasons that more and more incumbent firms have begun to grow rapidly. Firms of all kinds flourish in Tennessee thanks to its vibrant collaborative spirit and strong and enduring supply chain partnerships based on mutual investments in manufacturing excellence, workforce training, and technology deployment. Above all, firms invest in the state, grow, and increasingly export from Tennessee because it has sought to nurture a dense, diverse, and extraordinarily competent supplier network that is now world-class

- **A center of responsive, high-quality, and cost-effective workforce development** not just for its OEMs but especially for its growing array of SME suppliers. Thanks to a steady focus on both improved basic education and the nimble delivery of industry-focused training, the state emerges as a well-known center for timely, collaborative, and sustainable workforce solutions. Crucial to this emergence has been the alignment of alert, data-oriented management at the state level with strong "bottom-up" problem solving in the state's regions, where firms and workforce organizations work closely together to design and deliver efficient, cluster-focused training programs that reflect the best market intelligence and models available. Thanks to this alignment of the state and its regional consortia, Tennessee now possesses a true, region-based system for training and workforce development that addresses the needs of all AI employers, large and small, and not just its favored OEMs

- **A leading center of automotive technology exchange** among a diverse array of institutions and firms. What was once predominantly a production destination has become a well-known hot spot for process innovation, R&D, and technology development and diffusion. In this respect, the state now possesses an increasingly formidable innovation system, including state and private universities that have made key investments in relevant faculty specialists, and national and private-sector laboratories that proactively engage with firms to define research agendas and commercialize automotive technologies. At the same time, the state works to ensure the availability of the convening opportunities, exchanges, and financing that enable SMEs to move up the value chain rapidly in novel supplier components and processes. Increasingly, the supply chain garners worldwide repute for its competency on a cross-section of next-generation automotive technologies, ranging from powertrain electrification to lightweight composites, all of which ensure the global relevance of Tennessee's automotive industry well into the future

In terms of quantifying this vision, the numbers are intriguing. If the state's supply-chain density grew from six supply-chain employees for every OEM job to seven—essentially bringing Tennessee onto a par with present-day Illinois, which has one of the country's densest supply chains—it would mean an additional 12,000 Tennessee jobs. If over the next decade labor productivity grew just 1 percent faster annually than the auto industry's national average did over the last decade, then the state's auto industry will produce an additional $2 billion in output by 2023—50 percent more than today. Finally, if per worker private-sector auto R&D increased by 60 percent, bringing it on par with the Southern automotive average, that would result in an additional $57 million in R&D per year which, at the current rate, would represent an additional 2,900 patents in the Tennessee automotive industry.[1]

However, while completely plausible, this future is not assured. In the absence of strong and collaborative efforts to upgrade the industry by its large and small firms, state government, and local and state economic development organizations, Tennessee's future in the global automotive industry could be much starker. Under this scenario, five or 10 years of complacency and inaction could leave the state:

- **Relegated to a low-cost tier** in the industry, with its competitiveness mostly determined by its cheap cost structure and expensive incentive packages. On this front, an excessive focus on cost competitiveness could

weaken the state's industry by degrading supplier quality and interrelatedness, eroding worker pay and training, and precluding the investments in process engineering and new technologies needed to develop and market winning product innovations. Furthermore, without a vibrant, deep supply chain that exports globally, the state economy could find itself dependent upon the production activity of a handful of OEMs as it is determined by highly cyclical domestic markets

- **Reliant on a second-class workforce** at a time when workforce quality matters even more. In this regard, should other states and nations across North America strengthen their human capital faster than Tennessee, the state could very well see its attractiveness for investment decline. With skills crucial to productivity and operational excellence the state could easily lose its edge in siting competitions as competition sharpens and the bases for advantage shift beyond cost

- **Unable to create value through innovation.** Should it fail to enjoy the benefits of long-term knowledge-building in partnership with Tennessee government and research institutions, the Tennessee auto industry might find itself condemned to compete on cost alone and so experience more and more competition. Without hard-to-replicate knowledge or special process or technology advantages, the state's OEMs and suppliers—stuck in lower-value production niches—would then begin to lose contracts as new expansions and new foreign and untraditional entrants gravitate to non-Tennessee locations. As a result, the investment and jobs associated with the deployment of critical new technologies—such as carbon fiber body shapes and game-changing powertrain advances—could well not flow elsewhere

In short, the future of the Tennessee automotive industry remains uncertain. A concerted private- and public-sector push to move up the value chain in the next half-decade could secure expansion for the state industry and other AIs. By contrast, even well-intentioned business-as-usual could lead to decline.

In order to grow the auto industry to its true potential, then, Tennessee's industry and government leaders need to break with traditional, largely reactive economic development strategies and instead focus more assertively and strategically on targeted interventions aimed at ameliorating specific industry and policy weaknesses. These strategies should be motivated by the many disruptive changes in the global industry and be responsive to resource constraints. If successful, Tennessee's automotive cluster could offer insights into the dynamics of advanced industries more broadly, paving the way for other high-value industries to locate, connect, and thrive in Tennessee.

In this fashion, then, industry and government should work together to address the three major challenges identified in the previous chapter, each of which implies an associated positive strategy for increasing the competitiveness of the Tennessee automotive industry.

Along these lines, three major strategies for advancing the Tennessee automotive economy suggest themselves. Working together, the state's private sector and public and nonprofit communities should:

- **Drive continuous industry development:** Establishing and maintaining the state's competitive edge for advanced industries like the auto industry will require urgent moves to increase firms' operational prowess, foster the broad health of the supply chain, and tap new market opportunities. Efforts to maintain cost competitiveness should be accompanied by moves to promote the vibrancy of the overall cluster (not just its OEMs), develop forums for information exchange, and promote both exports and strategic FDI

- **Develop the workforce pipeline to strengthen Tennessee's AI skills base:** Tennessee faces a skilled worker shortage that threatens to be a pinch point in the industry's growth. A long-term commitment, starting now, that brings together industry and public-sector educational facilities to train, retrain, and attract the workers necessary for the automotive and AI sectors to be successful will be critical in the years to come

- **Commit to innovation at all levels of the supply chain:** With a number of technologically disruptive forces affecting the global automotive industry, the bottom lines of automakers and their suppliers in Tennessee will

ultimately be heavily influenced by how well the state's innovation system functions. The state should aggressively support efforts to increase commercialization, incentivize private-sector research, and expand suppliers' access to technology

* * *

The two chapters that follow suggest how the private sector and government can work together to ensure that the state's impressive and growing automotive economy is able to navigate disruptive global trends and invest in growth-oriented opportunities in the coming years.

Chapter VII explores how private-sector firms, working both individually and in collaboration, can heighten their global competitiveness, strengthen career pathways into auto manufacturing, and boost innovation activity.

Chapter VIII explains how the state government, working with the state's congressional delegation, can set a strong platform for continued growth in Tennessee's auto sector and in advanced industries more broadly.

In all of these strategies, though government can and should play a role, the private sector must take the lead in mastering disruptive forces and capitalizing on new opportunities.

In short, Tennessee firms and government should launch a collaborative new push toward auto-industry preeminence.

VII. THE PRIVATE SECTOR: SECURING ADVANTAGE THROUGH PRODUCTIVITY, SKILLS, AND INNOVATION

The drive to auto-sector preeminence will hinge above all on the success of the private sector. More than any other stakeholder, Tennessee auto firms possess the drive and know-how that will allow this advanced industry to thrive.

And yet, while individual operational excellence will remain imperative, cost factors will be increasingly intertwined with human capital and technology issues and companies will be less and less able to go it alone. More and more, in fact, the firms that excel are going to be those that most adeptly engage with supply-chain partners, engineering and service companies, industry networks, the public sector, and local institutions to drive down costs, cultivate a top-flight workforce, and add superior value.

In view of that, the strategies recommended here seek to suggest ways that Tennessee auto firms can simultaneously improve their individual performance while realizing the benefits of increased interaction in a more complex industry.

Along these lines, the state's auto companies should consider a number of strategic options arrayed across the three strategic priorities identified by this report. They should:

Drive continuous industry development

Tennessee auto firms should first maximize their competitive position by augmenting their industry's operational prowess, cluster dynamics, and links to new markets.

To start with, firms must continue to **increase competitiveness through operational excellence** and make that a hallmark of Tennessee auto manufacturing. Of course, enhanced workforce development is also critical. And over the long haul, targeted investments in R&D and breakthrough engineering will be essential to develop and market winning product innovations. But first and foremost Tennessee auto enterprises of all kinds must continue to improve quality and wring out costs by striving for best-in-class execution.

Many Tennessee auto firms—motivated by intense cost pressures and a lack of pricing leverage during the last decade—have already achieved significant efficiencies. As a result, many companies have positioned themselves for success. However, cost and other pressures in the industry show no sign of abating and most companies have exhausted the most obvious opportunities for cost-cutting. Thus, it is imperative that industry participants redouble their efforts to drive productivity through process excellence.

In this regard, the current return to profitability presents a chance for Tennessee auto companies to put in place the next round of procedures, processes, and equipment needed to confer advantage on at least two fronts: manufacturing procedures and logistics.

Along the production line, for example, now is the time for Tennessee firms to invest in new or enhanced manufacturing processes, such as making innovative components that employ high-strength metals or advanced composites. Through such manufacturing efficiencies firms can integrate lower-cost production techniques that cannot easily be duplicated and can thus confer a sustainable cost advantage.

At the same time, with firm operations becoming vastly more global, complex, and technology-driven, OEMs and suppliers each can respond to market-mandated cost givebacks by doubling down on supply-chain management. For all participants, better procurement and design and execution of logistics chains—taking advantage of Tennessee's optimal location and connectedness—represent an increasingly significant source of value.

And yet, if operational excellence plays out most immediately at the individual firm level, competitive advantage does not develop in isolation in the AI sector. To the contrary: advantage emerges almost invariably among networks of firms—geographically concentrated groups of interconnected businesses, associations, networks, suppliers, service providers, and associated institutions. Nor is the Tennessee auto industry an exception. Notwithstanding the national and global nature of the industry value chain, Tennessee OEMs and suppliers each rely on intricate "co-location synergies" that arise from siting near each other. These synergies are critical since they allow firms to more easily source inputs, locate workers, or profit from formal and informal knowledge exchange. What is more, many Tennessee firms are finding that the increasing density of the state's supplier network can accelerate the pace of problem solving, deal making, and idea sharing—providing efficiency.

All of which argues for Tennessee auto industry companies to step up their engagement in industrywide networking and, more specifically, **play a lead role in developing a more robust industry association** in the state. In general terms, Tennessee OEMs and suppliers should embrace the benefits of partnership and exchange and seek to strengthen that exchange, in part by working to create more channels through which it can occur. More specifically, the state's OEMs and suppliers should embrace the cause of creating a strong industry group to promote the future development of the state's auto sector. Such an association could conceivably sweep up and expand on the well-intentioned but under-resourced efforts of the Tennessee Automotive Manufacturing Association. Filling a void, such a new organization—adequately resourced—could serve as a much-needed forum for statewide network building, best-practice sharing, quality and manufacturing excellence training, collaboration on workforce development, technology scouting, and technical exchange. Ideally both OEMs and large and small suppliers would participate in an association that would among other things improve and deepen OEM-supplier relationships. But even if OEMs chose not to participate, the creation of a supplier-only association would be welcome. In any event, large and small firms alike should move energetically to match initial seed funding from ECD (that could be staged to decline over three years) and play the lead role in creating the new association and prioritizing its crucial activities. With such an association in place, the state will gain a valuable new convener and facilitator of essential cluster activities.

Building a robust industry association: best practices from throughout the country

Creating a state industry association from the ground up provides an important opportunity for stakeholders to work together to tailor the organization's structure and programming to the specific needs of the local industry.

For best practices in marketing and advocacy, the **Colorado Space Coalition** stands out for its role in promoting the state's space cluster nationally and conducting advocacy at the state and federal levels on behalf of its membership, which includes companies, academic organizations, research centers, and economic development groups as well as representatives from the military.

For best practices in programming, look to the **Indiana Manufacturers Association**, which serves as an information clearinghouse for its members and offers a range of seminars, events, and services focused on regulatory compliance, pending and enacted legislation, and topics of relevance to the state's broad manufacturing base.

In terms of supply-chain activities, the Economic Development Partnership of Alabama's **Process Improvement Training Team**, which assists SMEs with the design and implementation of process upgrades, offers a strong model.

True to its mission to "connect to innovate," the **Technology Association of Oregon** forges business-to-business and public-private linkages across the state's technology community by hosting networking events and facilitating technology exchange through thematic member-led forums.

For promoting innovation and commercialization few organizations are more successful than **San Diego CONNECT**, which links university and research systems with entrepreneurs, existing companies, and capital sources and also holds workshops and events on topics relevant to its stakeholders almost daily.

Finally, for cluster strategy setting, **Northeast Ohio's Nortech** shows how an industry organization can plot a course to achieve a regional industry cluster's medium-to-long-term vision through consensus-based industry and technology road mapping.

As these examples suggest, an effective industry organization must be tailored to the particular needs of an industry in a place. High-performance entities across the country have pioneered smart and transferrable models for different elements of an industry association that a new entity can emulate or adapt to fit its own mission and goals.

Sources: Colorado Space Coalition website, Indiana Manufacturers Association website, Economic Development Partnership of Alabama's Process Improvement Training Team website, Technology Association of Oregon website, San Diego CONNECT website, Nortech website.

But Tennessee auto companies also should look beyond operational strength and improved cluster dynamics to maximize their present competitive position. Most notably, current improved levels of profitability give Tennessee suppliers breathing room for bolder strategic thinking and action, including moves to **explore opportunities for expansion into foreign and non-automotive markets**.

On both counts, modest projected growth in the U.S. automotive market combined with fierce projected competition that will only grow more intense suggest that suppliers would be wise to assess whether they can use accumulated expertise or adapted products to enter new markets, whether automotive or non-automotive, to offset U.S. demand cycles and tap new revenue streams. Several sorts of opportunities exist.

To begin with, many suppliers will want to take a close look at exporting, given the extreme crowding of the domestic market and the fact that 70 percent of global purchasing power already resides outside the United States. However, individual firms' forays abroad will take different forms according to company size, product offering, and past experience. A company that already exports may redouble its efforts to market globally and enter new countries or trading blocs. SMEs

looking to export for the first time will likely want to seek out resources provided locally by chambers of commerce or regional economic development organizations as well as by state and federal export promotion programs and agencies. And for their part large multinational enterprises will want to revisit the economics of producing for export from Tennessee given quiescent U.S. energy costs, converging global wages, and domestic supply-chain stability. The business case in many circumstances may be compelling.

Likewise, some Tennessee auto suppliers may choose to explore opportunities in adjacent non-automotive markets. Numerous Tennessee companies possess technologies and capabilities currently deployed in auto production that are applicable to a range of other advanced industries, including aerospace, advanced materials, chemicals, medical devices, and advanced electronics. This, too, may open up opportunities for thoughtful diversification. To the extent such firms can initiate or expand their participation in such non-auto sectors, whether domestic or foreign, they may be able to hedge against future uncertainty in the auto industry by tapping into growth markets in which price and profit pressures may not be so severe. Moreover, while caution is always warranted, the cutting-edge operational and technical expertise that firms have honed in the tough competitive environment of the automotive industry should well position Tennessee suppliers to tap adjacent markets.

Develop the workforce pipeline to strengthen Tennessee's AI skills base

Tennessee auto companies, like firms in other AIs, must also focus intensively on establishing a stronger and more consistently effective workforce training pipeline.

Between the upcoming retirements of the baby boom generation and the ever-increasing skills needs of the industry, auto companies will face sizable workforce challenges for the foreseeable future. Further growth will only exacerbate those challenges. For this reason, OEMs, tier 1 suppliers, and SMEs alike—in partnership with each other and in conjunction with educational institutions and training providers—should act now to engage with the state's training organizations and work to establish strong, clear pathways to employment in the auto industry. Such efforts will involve several critical components.

In the most general terms, firms at all levels of the supply chain should **seek collaborative solutions to workforce training needs** that build on their existing associations, partnerships, and self-interest to formally identify and respond to existing and projected industrywide labor demands. OEMs, tier 1 firms, and SMEs must all be full partners in these endeavors; active and ongoing engagement must be the watchword. And in fact shared interest in cultivating a top-flight auto and AI workforce in Tennessee will increasingly draw firms into such active collaborations. The collaborations, meanwhile, can take a variety of forms. SMEs with similar training needs could take advantage of economies of scale by working with professional instructional task analysts to determine the skills that their employees need or by forming skills consortia on particular topics to provide training to incumbent workers and/or new hires. Likewise, OEMs and tier 1 firms could work with companies further down the supply chain as well as area educational institutions to develop and regularly update programs of study that meet the credential and competency requirements of existing and projected job openings in the auto industry. Through these collaborations, firms in the Tennessee auto industry can work to address the challenge of cultivating a sufficient, skilled workforce while at the same time building relationships between firms and throughout the supply chain.

More concretely, firms in the Tennessee auto sector should **lead in developing improved regional skills partnerships** that bring together key stakeholders—including community colleges and TCATs, workforce investment boards (WIBs), workforce intermediaries, chambers of commerce, industry associations, and regional economic development organizations—for the purpose of strengthening the regional workforce pipeline. In this regard, regions are the proper venue for action given the geography of labor markets, and employers must lead because only they know their exact worker needs. And so Tennessee auto-sector employers should play an active role in designing and implementing the employer-driven regional partnerships—such as the recently launched Middle Tennessee Skills Panels—that hold out so much promise for routinizing the delivery of appropriately trained workers to the sector. In many places, the building blocks for such partnerships are already in place through TCAT and/or community college advisory boards, WIBs, and other associations. That means that with active engagement, intelligence sharing, and leadership, employers in many regions can play a transformative role in uniting training system actors and the various tiers of the supply chain behind a common plan for sector-focused workforce development. At the same time, regular, open communication between companies and institutions of higher education will help ensure that courses of study offered align with current and projected labor needs.

Collaborating to address workforce development challenges: M-Powered

Strong workforce development solutions almost invariably involve the energetic engagement of both firms and education and workforce service providers. By working collaboratively, such partnerships are able to accomplish far more than an individual company can on its own.

In Minneapolis-St. Paul, the M-Powered program relies on just such a partnership to prepare workers for careers in the biomedical manufacturing sector. In 2004, a handful of manufacturers in the regional industry together realized that the workforce development challenges they each faced would be best met through collaboration. These firms approached Hennepin Technical College about creating a program that could provide both classroom and work-based training in biomedical manufacturing. Hennepin Technical College then sought grant support from the state and reached out to HIRED, a leading regional workforce development organization, which joined as a partner and helped launch the M-Powered program.

Companies participate in a variety of ways, including serving on the M-Powered board to help set direction for the program, contributing to curriculum development, offering paid work-based learning opportunities for M-Powered students, assisting with classroom instruction, and interviewing M-Powered graduates for available jobs. The curriculum combines preparation for industry-recognized credentials with other technical training and soft skills development in order to ready students for all aspects of their future careers. To help ensure student success, M-Powered also provides counselors who help students craft individualized career development plans and connect students to childcare and temporary employment.

Programs like M-Powered help ensure that educational and employment training programs are strongly tied to industry needs while also taking advantage of the economies of scale made possible when groups of firms work together to address common challenges. Taking M-Powered as a model, firms in other industries can work with area educational institutions and workforce development organizations to craft collaborative, industry-oriented solutions to shared education and training needs in order to ensure that employers are able to develop the skilled workforce they need for success.

Source: M-Powered website.

Related to the need for partnerships between firms and workforce intermediaries is a need for the direct immersion of students and prospective workers in firms. Only employers can facilitate such immersion, and so auto and other AI firms should move to develop or expand their relationships with area educational institutions to **increase the number of work-**

based learning opportunities. Work-based learning can help raise student awareness of particular career paths within a given industry while at the same time giving students the chance to acquire necessary industry-specific knowledge, skills, and experience. Active industry engagement on internships and cooperative education programs provided by universities, community colleges, TCATs, and high schools will increase student access to work-based learning, expanding the AI sector's pool of potential future workers in the process and helping to address employer concerns that recent graduates lack experience and industry-specific knowledge.

Finally, employers at all levels of the supply chain can enhance their ability to identify qualified job applicants by moving to **support the use of industry-recognized certifications** as a standard part of HR practices. Developed by the private sector, these nationally established certifications provide a clear indicator of the knowledge and skills possessed by the bearer of the credential while at the same time offering employers a coherent, standardized way to communicate the skills requirements of a particular occupation. The manufacturing sector has been a leader in developing and using these certifications, with the National Association of Manufacturers (NAM) Skills Certification System providing endorsement for a number of industry-recognized certifications that apply to all manufacturing sectors and multiple skill levels. Tennessee auto and other AI concerns should adopt the certification approach. Widespread adoption of industry-recognized certifications by both OEMs and suppliers would provide clear signals of skills needs not only to prospective workers but also to educational institutions that could then more easily shape training programs to industry needs.

Commit to innovation at all levels of the supply chain

Competitive operations and improved workforce development, however, will not be sufficient to maintain the state's position in the automotive industry. Innovation has now also become imperative, and Tennessee firms need to commit to it.

No longer will operational excellence, basic cost cutting, or mergers and acquisitions be sufficient to stay ahead of the global automotive market.

Instead, as competitive pressures in the industry ratchet up, Tennessee participants must as a general matter begin now to **concentrate on innovation** as a primary tool for value creation, whether to deliver process gains, unique capabilities, or new product offerings.

Currently, Tennessee auto companies focus too little on innovation. Consequently, they may be exposing themselves inordinately to the ferocious competition and thin margins that characterize the North American auto sector. And so Tennessee auto companies should now embrace technology innovation as an urgent general priority. Only through such prioritization will successful firms insulate themselves from the brutal cost pressures of the industry and "future proof" themselves through the development of unique product offerings, novel designs, new processes, and game-changing technologies.

Supporting supply-chain collaboration: Jaguar Land Rover

In order to address shortening lead times and the demand for higher-quality, innovative components, OEMs need to see their supply chain as a collaborative network and not simply as firms from which they purchase products. Jaguar Land Rover (JLR), the British automaker, is an industry leader in fostering coordination and support throughout its supply chain.

During the Japanese tsunami when most OEMs were completely disconnected from their lower-tier Japanese suppliers, JLR positioned itself as a steward of its supply chain by leaning heavily on its tier 1 suppliers to engage with lower-tier suppliers to address logistics and infrastructure problems. In doing so, JLR was one of the only automakers that did not

Jaguar Land Rover (continued)

experience substantial delays from its global supply chain. JLR also recognizes that suppliers represent the lion's share of innovation in the automotive industry. For that reason the firm relies heavily on long-term, flexible supplier relationships. This is one reason the company employs more flexible contract lengths than most OEMs and bases contract duration in part on supplier innovation and quality.

The company is also willing to share confidential information to support decisionmaking amongst key suppliers. For example, after the recession when suppliers were hesitant to build capacity JLR shared confidential five-year volume projections to help them make inventory decisions. JLR, along with a handful of other lead OEMs, has realized that whether the question be logistics, innovation, or quality control, automakers should consider their supply chain as a web of close partnerships that can define the success of an automotive product line. More of that spirit of enlightened self-interest will need to break out in Tennessee as the demand for quality, worker skills, and innovation ratchets up.

Source: Automotive Supply Chain Magazine*, 2013.*

As to how and where to take part, the most concrete way that firms can respond to the innovation imperative is by taking steps to **increase R&D investment**. In this regard, firms' own-source R&D spending represents a critical strategic asset because it represents firms' central mechanism for constructing value in anticipation of future customer needs and market trends. Given that, many Tennessee firms likely need to step up their R&D outlays sharply, not only to build new advantage but also to offset deficits associated with the fact that on a per worker basis Tennessee firms currently invest only about half as much on R&D as firms in other Southern states. Beyond deciding *whether* to invest, meanwhile, firms will need to decide on *what* issues to focus—whether general or narrow. On this question, individual firms will need to make highly strategic investments to shape a manageable technology portfolio, seeking to build hard-to-replicate knowledge and knowing that they cannot expect or afford to develop expertise on unlimited topics. Still, two prevailing technology imperatives appear generally pressing: the spread of electronics throughout the car and the need for a more fuel-efficient fleet. With state institutions and firms maintaining a measure of expertise in each of these areas, Tennessee suppliers should aspire to develop hard-to-replicate knowledge in select, attainable niches relevant to their businesses, such as the use of certain lightweight materials (including carbon fiber), aspects of powertrain electrification, applications in battery storage, and solutions in user-interfacing information technology. Firms that make smart decisions and execute will position themselves to compete profitably in the future.

And yet, firms' innovation strategies should not be isolated or restricted to "homegrown" internal initiatives. More and more, the locus of innovation in the AI sector is shifting outward toward networks, external partnerships, and the varied formal and informal exchanges of individual firms with outside institutions, the wider supply chain, and related regional innovation clusters. Accordingly, Tennessee firms should **prioritize engagement in the innovation commons** and work wherever possible to foster the emergence in Tennessee of a dynamic, multi-channel technology ecosystem in which OEMs, suppliers, business associations, universities, labs, economic development groups, and government interact in myriad ways to deliver innovation gains faster and cheaper than otherwise possible. Certainly such engagement must make sense to individual firms and deliver solid business value. But on balance, exchange and (on occasion) partnership on innovation and technology development topics are increasingly being shown to advance firms' interests and performance. As such, firms should look outward and seek to engage when appropriate. Sometimes the engagements may entail formal university research partnerships. In other instances, the linkages may take the shape of participation in user or affinity groups like ORNL's Carbon Fiber Composites Consortia, which facilitates information sharing and relationship building on the development and deployment of new lower-cost composite materials. And at other times, and more frequently, the exchanges may consist of formal or informal supply-chain convenings—perhaps organized by a revitalized industry association—aimed at facilitating information sharing relevant to particular technology priorities. Properly designed, such supply-chain convenings represent a low-cost way to facilitate information exchange, catalyze problem solving, and accelerate technology diffusion.

In sum, Tennessee auto firms should commit to innovation, both individually and as outward-looking participants in a synergistic innovation ecosystem.

Improving exchange across the supply chain: Original Equipment Suppliers Association town hall meetings

Even when suppliers develop innovative products they may lack opportunities to interact with large OEMs and tier 1s, making it difficult for them to break into large OEM supply chains. To address the lack of convening opportunities that bring together suppliers and OEMs, the Original Equipment Suppliers Association (OESA)—a national association of auto suppliers based in Michigan—hosts a number of annual "town hall" meetings between OESA members and OEMs, including Chrysler, Ford, GM, Honda, Nissan, Toyota, and Volkswagen.

These town halls are more than just meetings; they are opportunities for SME suppliers to engage with OEM executives and other key customers who rarely interact with these smaller firms. At these meetings, OEM officials offer insight into new purchasing decisions, vehicle engineering platforms, and cost- and quality-control initiatives, with limited press access so that suppliers and automakers can engage in candid conversations. To ensure that the town halls are relevant to suppliers, OEMs are tasked with bringing senior representatives to the meetings. For example, one year Honda brought its entire purchasing organization from Ohio to discuss specific changes to its product lines. Because town hall attendees are briefed directly by OEM decisionmakers, participating firms are able to receive timely, important information about the direction of the industry.

Over the years, OESA's town halls have developed a reputation for fostering important and relevant industry dialogues between OEMs and suppliers. Convening opportunities such as OESA's town halls help SME suppliers understand how OEM needs are evolving while at the same time allowing OEMs a greater understanding of both the problems that suppliers face and the new technologies that suppliers have in the pipeline. Tennessee industry leaders should consider convening similar dialogues.

Source: Original Equipment Suppliers Association website and interview with Glenn Stevens, OESA.

* * *

Industry, in the end, will play the leading role in determining whether Tennessee does or doesn't move up the global auto-production value chain. Tennessee firms will drive growth in large part by doing what they do best: executing their strategies and improving their individual performance, week to week and quarter to quarter. However, it is also in firms' self-interest to recognize that value will increasingly flow from workforce quality and innovation and that companies competing on those fronts will likely require greater collaboration—with other firms or with public-sector and other third-party actors. In this respect, Tennessee firms should recognize now that their individual competitive advantage will increasingly depend on the competitiveness of the state's broader web of local capabilities, relationships, and institutions and move to build up that web as a new competitive asset.

INDUSTRY AGENDA

$ = Little to no cost	**$$** = Low cost	**$$$** = Moderate cost	**$$$$** = High cost

Drive Continuous Industry Development

Increase competitiveness through operational excellence	**$-$$$**
Play a lead role in developing a more robust industry association	**$$-$$$**
Explore opportunities for expansion into foreign and non-automotive markets	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Seek collaborative solutions to workforce training needs	**$-$$**
Lead in developing improved regional skills partnerships	**$$-$$**
Increase the number of work-based learning opportunities	**$$-$$$**
Support the use of industry-recognized certifications	**$$**

Commit to Innovation at All Levels of the Supply Chain

Concentrate on innovation	**$-$$**
Increase R&D investment	**$$$$**
Prioritize engagement in the innovation commons	**$-$$**

VIII. THE PUBLIC SECTOR: CATALYZING ADVANCES IN PRODUCTIVITY, SKILLS DEVELOPMENT, AND INNOVATION

The public sector—and especially state government—has its own critical role to play as Tennessee auto companies seek to move up the value chain by complementing cost controls with human capital and technology capabilities. More and more, governments are recognizing that they must engage to safeguard and extend industry advantage. The new dynamics of global competition require it.

And yet, the government engagement of the next phase must be quite different from that of the recent past. No longer can auto states rely so heavily on the attraction and financial support of "billion-dollar" plants as their main strategy. And neither can the federal government any longer neglect its responsibility to attend to the fundamentals.

Which is why a new stance is required—one that is at the state level catalytic and facilitating (rather than all-determining), even as it is supportive and empowering at the federal level.

Specifically, the next few years call for the state government in Tennessee to play an entrepreneurial, brokering role in catalyzing responses to the several collective-action problems that seem to hobble industry collaboration on key aspects of industry competitiveness, workforce development, and technology diffusion. At the same time the new era demands that Washington deliver, after too much delay, on a limited but essential list of platform-setting goods that only it can provide: trade liberalization and market access; certain education supports; and basic and applied research investments at scale.

In keeping with that, the state government—working with its congressional delegation—should organize its next automotive efforts around the "Drive!" agenda's three strategic themes. Here are the recommendations:

Drive continuous industry development

The first priority in the current period of relentless competition must be for the state to help the auto industry—and eventually other AIs—enhance its general competitiveness. To do that the state has a role to play in promoting collaboration and connections to new markets.

Both collaboration and a turn outward will be critical in the next phase of the Tennessee auto story. However, for the state to facilitate progress on either front it will first need to update its general approach to industry development so as to **focus on groups of firms, SMEs, and the supply chain** much more than it does now.

To date, the state has done a good job of delivering on what might be called, respectively, the "macro" agenda and the "micro" one. That is, the state has worked hard to improve the general business environment that affects all firms (with a "macro" focus on low taxes, lean regulations, and business-like government) while at the same time focusing intensely on the specific needs of individual firms (with a "micro" emphasis on providing individual relocation inducements, infrastructure projects, or worker training money).[1] Frequently the "micro" agenda has entailed a strong focus on securing major investments from large OEMs and tier 1 suppliers.

Going forward, however, the increased importance of how groups of firms interact to "compete together" will make it important for states to develop what can be called a "middle" or "meso" strategy—one that seeks to strengthen the institutions, programs, networks, and regional industry clusters that address companies' needs through relevant joint actions.[2] In keeping with that, the state should go farther than it has in focusing activities on initiatives that either provide shared benefits to AI industries or else foster exchange and collaboration within them. In this respect, the state should henceforth focus relatively less on the needs of individual firms and relatively more on the shared needs of the entire industry for problem solving on quality control; labor market issues; technology development; and efforts to optimize how institutions, firms, and other actors interact. Ideally, this shift of focus would see the state reduce its spending on external business attraction efforts and shift resources to in-state investment. Likewise, the new focus would see the state focus more on filling gaps in SME clusters and less on attracting big OEMs. Moreover, the state should take every opportunity to communicate this new focus. Communicating the new stance will at once affirm the importance of "coopetition" and convey a compelling story about the state's increased supplier density and the potential synergies and efficiencies it provides.

In terms of implementing the new approach, the state needs to better organize itself. To that end, the state should consider two actions that will allow it to catalyze the kinds of industry development that the state needs. First, the state should **name a "sector lead" in state government** to spearhead automotive industry development. Currently, the state lacks both a systematic strategy and adequate capacity for executing to develop its largest AI. Instead, while large-firm or relocation inquiries get dealt with ably, the reactive nature of the work often distracts from the steadier approach needed to grow the supply chain over time. In contrast, naming a hyper-focused sector advocate to set and execute the state's new strategy would allow the state to improve its recruitment work while at the same time focusing more intently on growing the industry. Based within ECD, the sector lead would work both to improve the state's game and proactively contribute to industry initiatives. To the first point, this full-time professional would work to articulate the new strategy, apply it to

Driving industry development: Maryland's Director of Cyber Development

Having identified cybersecurity as a priority advanced industry for the state, Gov. Martin O'Malley of Maryland earlier this year appointed a director of cyber development to lead the state's push to become the epicenter of cybersecurity

Maryland's Director of Cyber Development (continued)

industry activity. The position is the culmination of a whole line of targeted programming in the state that includes specialized tax credits and education initiatives. The director's responsibilities include leading the governor's cyber agenda as well as advocating for the continued expansion of cybersecurity programs in the public and nonprofit sectors, attracting new cyber companies and investors to the state, assisting startup cyber firms, supporting relevant education and talent development activities across the state, and representing the cluster externally by, for example, leading industry delegations to national conferences. The position resides within the Department of Business and Economic Development.

Coordinating the many cyber-related initiatives and actors in the state is one of the position's most critical functions. The director works closely with CyberMaryland, a public-private partnership called for in the 2010 CyberMaryland report, which articulated a clear strategy for industry development in the state. As an organization, CyberMaryland joins together industry, academia, investors, technologists, entrepreneurs, and government to connect Maryland businesses with R&D, education, workforce, and contracting opportunities to advance the industry in the state. The cluster encompasses 13 educational institutions certified as centers of academic excellence in cybersecurity by the National Security Agency, which also happens to be headquartered in the state along with several other federal, military, and intelligence cyber assets. One of the director's first big projects will be to develop a National Cyber Center of Excellence in partnership with the National Institute of Standards and Technology.

Recognizing the significance of the cybersecurity industry to Maryland's economy and the full breadth and depth of active players in its cluster, the state invested in a single point person to coordinate activities and focus exclusively on driving industry development.

Sources: CyberMaryland website, Maryland Department of Business and Economic Development website; and Office of Gov. Martin O'Malley, "Gov. O'Malley Promotes Cyber Initiatives to Create Jobs and Fuel Innovation"

relocation and growth efforts, and align state efforts with industry priorities. To the second, the new advocate would work to actively leverage the state's convening power, programs, and assistance to solve problems and seize opportunities quickly. The bottom line is that the state needs and should establish a go-to professional tasked with doing whatever it takes to move the Tennessee auto industry up the value chain.

Second, the state should consider moving to **catalyze the creation of a robust automotive industry association** to market and advocate for the industry and facilitate networking, learning, and supply-chain activities. Right now, the state lacks such an association given that TAMA is mostly a well-intentioned labor of love with too few resources to make a big difference. As a result, efforts to advance the industry remain diffuse and disparate, with suppliers and SMEs especially losing out due to the lack of a strong membership forum. The launch of a well-designed and well-resourced industry association with a time-limited, declining seed grant from the state would provide the industry with a much-needed focal point not just for typical marketing, advocacy, and coordination efforts but also for critical convening and networking functions. To the latter mission, the new organization would serve as an important forum for both structured and unstructured exchanges on key issues of importance to the Tennessee auto community, ranging from manufacturing excellence and quality control to worker training and technology. In this way, the new organization would solve a significant collective action problem in Tennessee by providing the state a needed forum for greater information flow and problem solving. The state should help get such an association started by convening the relevant players and challenging industry to invest. For the first time Tennessee would have in place—by dint of the sector lead and a solid industry association—the infrastructure necessary for an industry-government partnership to execute on key priorities.

At the same time, the state should "go global" and **emphasize international engagement, both by "doubling down" on export promotion and linking export and FDI promotion.** In this connection, few auto states know better than Tennessee the importance of international commercial relationships, given the role of foreign-owned firms and their exports in the Tennessee auto story. Accordingly, the state should assert new leadership by better exploiting the potential synergies

between its heavily internationalized industry and both export and FDI opportunities. Progress has already been made with the development of ECD's international strategy. Now, the state must be sure to follow through on its policy outline now that the federal STEP program is gone. To do that, the state—working through the proposed sector lead—will need to work intensively to leverage multiple sorts of relationships to generate new activity. To help more Tennessee firms export, for example, the state should invest directly in export promotion to replace the federal support from the sunsetting STEP program. In doing this, meanwhile, the state's sector lead will want to multiply the state's capacity by enlisting any and all potential partners, including the state's lineup of regional chambers of commerce, in the effort. Similarly, to cultivate FDI, the state should systematically exploit the already sizable presence of foreign-owned firms to promote further investment or entirely new investment. And the state should go further and work deliberately to join its export and FDI efforts into a coherent international strategy, one rooted in Tennessee's needed cluster strategy and designed to capitalize on the state's competitive advantages in international markets. In this vein, FDI should no longer be considered merely an extension of business recruitment but should be viewed instead as a strategy for bringing strategic capabilities and foreign capital to Tennessee to grow and strengthen the state's industry base. FDI should also be considered as a strategy for building export capacity. Not only might FDI firms use Tennessee as a base for export production, but the infrastructure that production-oriented FDI often requires to bring imports in can also boost the capacity of nearby firms to take exports to market. Likewise, export promotion should be practiced in ways that simultaneously leverage the international ties of Tennessee's existing foreign companies and cultivate new FDI opportunities. Only through such efforts will Tennessee be able to scale its efforts up sufficiently to move the dial on global engagement and competitiveness in an appreciable way.

All of which raises a final priority for global engagement and elevated competitiveness: Tennessee's political leadership—in close coordination with industry—should advocate forcefully for trade liberalization and regulatory harmonization at the national level. Currently, the nation's lack of bilateral trade agreements with such large economies as Brazil, China, the European Union, India, and Japan is demonstrably undermining Tennessee's competitiveness as a platform for both FDI and exports as Mexico busily continues to secure favorable access to large and growing markets. Therefore Gov. Haslam needs to emerge as a leading advocate of trade liberalization and work with the state's congressional delegation to secure these agreements. Without them, no amount of execution on FDI and export promotion will yield as fully as it could.

Develop the workforce pipeline to strengthen Tennessee's AI skills base

And yet, the state must do more than strengthen its industry development activities. State government needs to get serious about upgrading Tennessee's workforce system—something it has begun to do with Gov. Haslam's appointment of a special advisor for higher education last winter and with the legislature's passage of the Labor Education Alignment Program (LEAP) this past summer.

There is much work to be done. Not only are legacy arrangements and institutions struggling with the new demands of a fast-changing economy, but Tennessee represents a particularly complicated situation with its wide variety of firm profiles, more than two dozen labor markets, and complex administrative lines.

Moreover, the state has to date primarily focused on meeting the needs of OEMs and other large firms while paying less attention to the needs of the state's hundreds of SMEs, which are less able to dedicate resources to workforce training and development.

However, it's now time to get to work and begin to build a truly state-of-the-art workforce development system—one that is, like the best systems, regionally based, industry-focused, and performance-driven. Ideally the new system will focus on devising high-quality multi-employer training programs rather than single-employer one-offs.

To start the new push the state should **create an AI skills champion** in state government. Similar to the sector lead, the skills champion would be tasked by the governor with promoting a new vision of workforce development in Tennessee. This new point person would coordinate efforts to improve the state-level system while at the same time aiding and abetting "bottom-up" regional ones. Currently, the state lacks such a driving force. With little direction setting and coordination at the state level and no mechanism for promoting best practices, the state makes do with a disjointed and inconsistent array of workforce efforts around the state, all of which appears to confuse employers and yield variable outcomes. Appointment of the skills champion would help remedy this situation. Charged with improving the present state of affairs, this full-time professional will work on two fronts.

At the state level the skills champion will work with the Department of Labor and Workforce Development (DLWD), the Tennessee Board of Regents (TBR), the Tennessee STEM Innovation Network, and other state-level stakeholders to coordinate the state's offerings and activities in keeping with the state's emerging sector-focused, region-oriented AI agenda. Importantly, the skills champion will work especially to improve communication and collaboration across state agencies in order to promote a more integrated state approach to education, workforce development, and economic development. The skills champion will also work with DLWD and TBR to develop a shared, effective strategy for marketing training services to Tennessee AI firms and companies interested in locating in the state.

At the same time, the skills champion will deploy the convening and agenda-setting power of the state to promote breakthrough problem solving in the state's regions. Employing a "bottom-up," action-oriented approach, the skills champion will play a catalytic, supporting role throughout the state by helping employers and their partners work out new training solutions on the front lines of the state's labor markets. To multiply the gains, the skills champion will work to expand the reach of strong solutions by facilitating the sharing of best practices from around the state through virtual and physical exchanges and convenings. In addition, the skills champion will also work to improve access to relevant data; manage state-level skills gap analysis and demand planning efforts; connect regional stakeholder groups to technical assistance as needed; and put in place an effective performance management system. In this way, the state—through a well-chosen professional hire—will gain a critical point person for reform.

However, the skills champion is just one dedicated professional who can only do so much. The scale of the state's reform challenge remains enormous, however, given Tennessee's complicated geography (including four major metropolitan labor markets and 22 smaller ones) and sprawling training infrastructure. Literally hundreds of enterprises are currently administered by scores of organizations ranging from state-administered universities, community colleges, and TCATs to local WIBs and private companies.

And so the state needs to give itself more leverage in promoting the development of more consistent region-based, industry-focused collaborations aimed at closing skills gaps in Tennessee AIs. To that end, Tennessee should **establish an AI skills challenge grant program** to award funds on a competitive basis to strong initiatives in those regions working most creatively to align skills training to industry demand in the state's key industries.

In itself the skills challenge is hardly a panacea. The initiative would leave to another day any wholesale reorganization of the state's fragmented and variable delivery infrastructure. However, the skills challenge would launch the reform process in a serious way by leveraging limited funds for greater return and providing a strong incentive for new local and industry engagement and matching investments in education and training. Along these lines, the AI skills challenge would award two

Encouraging innovation in regional workforce development: Washington State's High Skills High Wages Strategic Fund

Rising skills requirements and imminent retirements in today's workforce underscore the importance of developing industry-driven educational and employment training systems that can effectively prepare individuals for career opportunities in the automotive industry and other AI sectors. However, given the many stakeholders involved, truly collaborative, industry-led approaches to workforce development remain elusive for many states and metropolitan areas

Washington State's High Skills High Wages Strategic Fund (continued)

throughout the country.

Washington State's 2008–2010 High Skills High Wages Strategic Fund offers one strong model for how state government can work with its regions to foster the emergence of regional, industry-oriented economic and workforce development efforts. Taking regionally designated industry clusters as its focus, the Strategic Fund offered competitively awarded planning and implementation grants to cross-sector regional consortia working to develop innovative approaches to workforce training and economic development in a particular industry.

By requiring collaboration among key stakeholders—including the private sector, area chambers of commerce, regional economic development organizations, K-12 and postsecondary institutions, and workforce development organizations—as a condition of eligibility, the Strategic Fund provided direct incentive for the types of collaboration needed to align workforce training activities with ongoing and emerging industry needs. Furthermore, in stipulating certain elements of program design, such as an emphasis on pathways to middle-skill jobs, stakeholder co-investment, and rigorous performance measurement, the grant competition aimed to encourage the adoption of critical best practices from the start. Through both its eligibility requirements and its provision of funds, the High Skills High Wages Strategic Fund demonstrated how a single state-funded program can stimulate creative problem solving that addresses the most pressing workforce challenges facing regional industry clusters. Such a fund offers a usable precedent for any effort by Tennessee to catalyze workforce system reform through a bottom-up innovation challenge.

Source: Washington Workforce Training & Education Coordinating Board, "2008-10 High Skills, High Wages Strategic Fund: Request for Proposals"

types of grants on a competitive basis: one-year organizing grants to support the development of plans for improving the connection between the region's education and workforce training systems and area AI firms, and multi-year implementation grants to support the implementation of such plans. These grants would range in value from $50,000 to $150,000 per year and would require at least a 1:1 match from the private sector and/or philanthropic organizations. As opposed to more prescriptive, top-down reform approaches, the skills challenge grants would stimulate system change more organically by affirming and expanding the kind of bottom-up problem solving that is already beginning to make progress through efforts like RCAM in Kingsport and the Middle Tennessee Skills Panels.

At the same time, though, the new program will exert significant directed change and system building through its criteria for successful proposals. Eligibility requirements would strongly incentivize such critical priorities as a regional focus; deep industry involvement; strong use of quantitative data on economic and labor market realities; plans for active, sustained engagement of industry with particular attention to the training needs of SMEs; well-defined metrics and performance management; and replicability, to allow for possible transfer to other regions. The state, meanwhile, would aid and abet the new problem-solving efforts by supplying high-quality data for demand planning and performance management; disseminating best practices; connecting grant recipients to technical assistance; and facilitating exchange among implementers. Along these lines the skills challenge would start the work of reforming the Tennessee workforce development system from the bottom up. As such, an open skills challenge in the form of a competitive matching grant will serve as a compelling "jump ball" that will give the state leverage to motivate change by incentivizing existing actors to align their activities in beneficial ways. In this fashion, the skills challenge allows the state to achieve sizable reform by inducing significant voluntary realignment.

As to further reform initiatives, many others may be needed in the coming few years—and could be spearheaded by the skills champion. For example, Tennessee would do well to embark on a campaign to inspire interest in AI-sector careers among students, parents, and the community at large in order to increase the pool of potential workers in the sector. Likewise, Tennessee could establish an advanced industries fellowship program to address higher-end skills needs that would connect graduate and postgraduate STEM students to work opportunities at AI firms. Through this program, companies would gain direct, low-cost access to highly skilled individuals, and fellows would obtain work experience that

would engage them in the AI sector and potentially help them obtain employment following graduation. And the state may want to explore emerging comprehensive models for training response being developed in other states.

In the meantime, though, at least one additional initiative should be undertaken now: The state should work to **expand access to work-based learning opportunities** within the AI sector. Internships, apprenticeships, and cooperative education programs have all been shown to have the potential of significantly reducing skills gaps. For employers, these hands-on experiences allow for practical, specialized work-based recruitment, training, and skills building. For students, the immersions provide practical experience that can yield a better feel for an industry along with the acquisition of the specific skills, knowledge, and work experience useful for getting a job after graduation.[3] However, while a number of universities, community colleges, and TCATs in Tennessee currently provide internships and cooperative education opportunities, the efforts remain disparate, variable in quality, and under-marketed. And so the skills champion should launch a serious campaign to expand the state's array of quality work-based learning opportunities, scale them up, and enhance their accessibility. Central to this initiative would likely be the development of a comprehensive, continuously updated statewide web portal and database aimed at cataloging, presenting in one place, and publicizing the availability of work-based learning opportunities at Tennessee-based AI firms. This searchable, web-based tool would provide students direct access to existing opportunities while at the same time assisting employers in their search for suitable candidates. With support from Tennessee's institutions of higher education, which would play a critical role in publicizing the tool to students and area companies, a state-led database could go a long way toward encouraging greater use of work-based learning in the state.

Commit to innovation at all levels of the supply chain

Finally, the state needs to get into the game on technology innovation.

With innovation and worker skills equally foundational for AI value creation, it is good that the state has begun to work on upgrading Tennessee's workforce development system. However, the time has also come for the state to take steps to improve Tennessee's technology development and diffusion environment.

Only by embracing technology development and diffusion as a top state priority will the state auto and AI sectors have a shot at developing the unique capabilities and technology specializations that will allow it to move up the value chain.

A recommitment to innovation in Tennessee must begin with a new resolve to **prioritize technology development and diffusion** across the auto and AI supply chains. Tennessee is known for its aggressive efforts to attract business and maintain its low-cost status. This year the state has begun to focus on workforce development. Now, the state should complement the initial IT and entrepreneurship-focused activities of LaunchTN with a new focus on the special needs of the state's AIs.

What would this new focus look like? Most notably, it would complement the state's current focus on entrepreneurs and startups with a new concentration on the steady accumulation of technical capabilities across the state's innovation commons. At every step the state should work to help Tennessee accrue hard-to-replicate industrial know-how, unique technical knowledge, and leading-edge process and product experience. Some of this new focus will entail steadily working to strengthen the state's key research institutions—UT and ORNL—and foster tech transfer. But an equal portion of the needed work will involve highlighting the importance of technology development to AI competiveness and helping to support the kinds of technology exchanges, information sharing, and supplier networking critical to the cluster development work that will be undertaken by the revitalized industry association. Such efforts should also extend to the state's firm outreach and recruiting. In this respect, it would fit the state's emerging AI strategy to prioritize the growth and recruitment of medium-sized, "innovation-ready" firms that fill a gap or key niche in the state's innovation commons. Special outreach to this class of strategically valuable firms could help fill holes and build advantage.

But prioritizing technology diffusion as a general matter leaves unaddressed the state's relatively weak innovation fundamentals. On this front, Tennessee needs to begin to address its sub-par positioning when it comes to conventional metrics of private-sector R&D, university and lab tech transfer, and fundamental research activity.

To the first issue, the state should move to **encourage private-sector innovative activity.** In the end, own-source investment in critical process and product innovation remains one of the most fundamental indicators of industrial competitiveness. For that reason, no indicator of the state's weak status on innovation should worry Tennesseans more than the state's low and declining levels of private-sector investment in innovation. And so the state should consider how it might encourage private firms to step up their innovative activities in Tennessee. Fortunately, two good options exist. One is the implementation of a state R&D tax credit, which eight of the state's 12 automotive peer locations maintain. Economic studies show that R&D tax credits encourage private-sector investment by reducing the effective cost of innovative activity.

Given that, a top priority for the legislature should be to institute a credit that would be competitive with the R&D credits offered by peer states. To that end, any new Tennessee R&D credit should exempt between 3 and 10 percent of the taxpayer's qualified research expenses from taxes and include a carry-forward provision to offset future profits, which is essential for startups that may not have profits during their early years when they invest most heavily in R&D.

Encouraging SME innovation activity: Innovation Vouchers

For small and medium-sized firms, engaging in innovation activity can mean the difference between remaining competitive and falling behind, particularly as higher tiers in the supply chain adopt new technologies and production processes. However, the actions needed to maintain an innovation edge can prove cost-prohibitive for SMEs, resulting in underinvestment and, over time, diminished competitiveness.

States can help SMEs surmount this affordability problem by making available innovation vouchers—a relatively new mechanism for stoking innovative activity among small and medium-sized firms. Under such a program, an SME seeking help with a particular innovation-related challenge can apply for a simple voucher, which can be used to pay for specific services provided by a research institution. By providing direct financial support for smaller companies seeking external assistance on innovation-related concerns, innovation vouchers have several benefits. Not only do they directly enable SMEs to get into the innovation game but they also catalyze more dynamic exchanges between R&D enterprises and private firms. And the vouchers are being shown to work. In both Austria and Holland, to take just two examples, innovation voucher programs have been shown to stimulate innovation activity otherwise unlikely to have transpired while at the same time encouraging increased levels of networking between research institutions and SMEs.

The innovation voucher program administered by Canada's Alberta Innovates Technology Futures (AITF) offers a strong model for states interested in finding new ways to support innovation activity among their SMEs. For the past five years, the AITF innovation vouchers program has helped early-stage tech firms obtain external assistance on business development and technological challenges. With two levels of voucher support—$15,000 and $50,000—that can be used to cover up to 75 percent of recipients' allowable project costs, the program's quarterly voucher awards aim to help small firms make the transition from early-stage to growth-stage more quickly, bolstering area industry clusters and strengthening Alberta's innovation ecosystem in the process. Since the first round of voucher awards in October 2010, the program has provided over $5 million in assistance to 243 companies in the province of Alberta.

Sources: Stephen Ezell, "Lessons From Foreign Countries on How U.S. States Can Spur Manufacturing"; Alberta Innovates Technology Futures Innovation Vouchers Program website.

Alternatively, the state could adopt a more direct approach and institute an innovation vouchers program for AI-focused SMEs. SMEs in Tennessee typically lack both the resources and the technical capacity to make strategic investments in

innovation. Yet they are fertile ground for potential impact given the known growth potential of small and mid-sized companies and their more frequent local ownership. Therefore, the state should provide to competitively selected small firms a simple voucher that would allow firms to "buy" R&D expertise from universities, national laboratories, or public research institutes inside or outside the state. These vouchers, which would range in value from $5,000 to $50,000, could be used for a variety of purposes, including technology scouting, technology assessments, problem analysis, process innovations, or intellectual property management. In addition, SMEs' use of the vouchers would have the added benefit of more closely aligning the interests of firms and academia and giving universities and labs greater incentive to be more responsive to industry needs.[4] In this fashion, an innovation voucher program would at once spur innovation in supply-chain SMEs and enrich the innovation commons by stimulating vital exchanges between industry and research centers.

Turning to the question of technology transfer, the state needs to make sure that it leverages to the fullest the commercial potential of the sizable public R&D activity now ongoing in Tennessee. To be sure, the state's existing public research activity tilts more toward the health sciences than toward those specializations more relevant to the auto or manufacturing sectors. Nevertheless, the state's relatively weak tech transfer performance across the board counsels a renewed bid to **encourage technology transfer from UT and ORNL.**

On the university side such a campaign will entail continuing the promising recent upgrades that are being implemented by David Washburn, president and CEO of the UT Research Foundation. After a period of redirection, UTRF is finally positioned to move technology out of the university more rapidly. Now the organization needs to inject energy into its programs by become more involved in faculty research, expanding its market portfolio and becoming a more active partner with the private sector. At the same time, the state—in partnership with business, the reenergized industry association, and Tennessee's congressional delegation—should take another run at unlocking for local use the tremendous AI value that resides within ORNL. Some will say such an unlocking has been tried and will always founder on the institutional structure and culture of the federal lab system. However, new leadership at the Department of Energy and the fact that the lab's private management contract is up for renewal in 2015 suggest the time may be right for better linking the lab to the local AI community and especially the auto supply chain. As such, the state should make it a high priority to strengthen and expand Tennessee companies' access to ORNL equipment, technology, staff expertise, and ties to international industry networks.

Connecting small businesses to national lab expertise: the New Mexico Small Business Assistance Program

With two of the largest national laboratories located in the state, New Mexico understands that the wealth of expertise and technologies found in these institutions can directly support economic growth, particularly among small businesses. Therefore, it has acted creatively to help its small businesses tap that wealth of knowledge.

To encourage New Mexico small businesses to make use of the resources available through the national labs, the state legislature in 2000 created the New Mexico Small Business Assistance Program (NMSBA). NMSBA provides SMEs modest non-matching grants ranging in value from $10,000 to $20,000 to purchase staff hours at either Los Alamos or Sandia national laboratories. Utilizing the grants, firms can link up with lab personnel for assistance with site selection, testing, consultation, or technical problem solving.

The program also provides larger grants for groups of firms seeking collective assistance for shared technical challenges through its "Leveraged Projects" program. Although each lab independently administers NMSBA activities, the state funds the effort by providing each lab a $2.4-million state tax credit. Since its inception, the NMSBA program has bolstered New Mexico's regional economies by assisting over 1,000 small businesses. By providing cash-strapped SMEs the means to invest in innovation activity, NMSBA has helped hundreds of New Mexico small businesses access the resources of two world-class institutions with which they would otherwise never have connected and so keep pace with technology change.

Source: New Mexico Small Business Assistance Program website.

Encouraging cross-sector, cross-regional collaboration on automotive R&D: AUTO21

Most industries face coordination problems when trying to collaborate with the public sector and universities. AUTO21, Canada's national automotive research program, works to overcome this challenge by bringing the public sector, industry, and academia together to conduct joint R&D projects on a distributed basis across much of the nation. Through the program, 44 universities, 300 researchers, and 240 public- and private-sector research partners collaborate to generate technologies that can be commercialized by Canadian automotive firms.

The AUTO21 Network of Centres of Excellence, located regionally throughout the country, conducts this research, which currently includes over 50 unique research projects ranging from advanced telematics to the development of lightweight biomaterials. In addition to basic and applied research, AUTO21 also provides opportunities for nearly 500 students to train, intern, or perform automotive research as part of their advanced degrees.

To reinforce the importance of industry-led research, a minimum of 50 percent of each student's research is required to take place within a firm. By providing a single institution tasked with bringing together public and private research across multiple locations, AUTO21 helps the Canadian automotive industry overcome serious coordination problems and maintain its innovative edge. As Tennessee and other Southern states explore the possibility of developing a multi-state regional automotive technology development consortia, they should consider the structure and approach of AUTO21 as a possible model.

Source: AUTO21 website.

What are some action steps? To start with, the state government should become a lead advocate at the federal level for national laboratory system reforms that prioritize regional partnerships and allow greater local independence, new funding models for all advanced industries firms, and broad SME engagement, in particular. Second, the governor's office and ECD should use their convening and facilitating powers to encourage higher levels of interaction and engagement between ORNL and Tennessee firms. In particular, the state could support more frequent events relevant to AIs such as the ORNL

Bridging the Gap conference and encourage the emergence of technology exchange organizations such as the Carbon Fiber Consortium. The state could also provide funding for direct technical assistance or laboratory use for firms in advanced industries. At the same time, a program of modest state support could help lower the barrier to engagement by providing financial assistance for SMEs looking to take advantage of ORNL's extensive technical capabilities. This material support could take a variety of forms, including the innovation voucher program outlined above or small-scale grants ranging from $5,000 to $20,000 offered to SMEs to "purchase" ORNL staff hours to assist with design, testing, site assessments, or economic and scientific analysis. Such a program could be modeled after the highly successful New Mexico Small Business Assistance (NMSBA) program that helps SMEs gain access to Los Alamos National Laboratory and Sandia National Laboratories.[5] Supported by a $2.4 million state tax credit to each laboratory, the program allows SMEs facing a technical challenge to collaborate at no cost with lab scientists or engineers on projects that require testing, design consultation, or access to special equipment or facilities.

However, technology transfer policies will only be as successful as the state's underlying technology capabilities. For that reason, the state needs in the moderate to long term to **continue building its advanced industry knowledge base**. One initial starting point may be to establish strategic partnerships with neighboring states that support regional AI capabilities. In this regard, the state should further explore the Southern Automotive Research Agenda (SARA), organized by the Center for

Strategic technologies for building advanced industry competitiveness

A surprising consensus exists about the emerging technologies that will be critical in the next era of U.S. advanced industry competitiveness. Applicable to multiple industries (not just auto, or manufacturing), these "crosscutting" technologies constitute appropriate areas on which to focus the state's strategic investments in the coming decade.

Strategic technologies for building advanced industry competitiveness (continued)

Among the most potentially pivotal themes are:

- **Adaptive and flexible production**: Flexible production allows a single production facility to produce a variety of product lines and quantities.
- **Additive manufacturing:** 3D printing is the additive process of building objects through layering. Additive manufacturing has the potential to substantially reduce the cost and time of one-off prototyping required in virtually all production industries.
- **Advanced analytics, "big data":** Big data refers to data sets that are too large for traditional computing tools and require unique software and skilled technicians to store manage and analyze.
- **Flexible and printed electronics (roll-to-roll):** Advances in printed electronics allow for large sheets of malleable circuits that will not only revolutionize electronic products but re-economize scale in advanced industries that rely on electronics, such as photovoltaics.
- **The Internet of things:** Advanced software, robotics, and network connectivity allow objects to be digitally linked and to interact.
- **Joining and interfacing**: Improving adhesives and bonding techniques allows OEMs greater strength and flexibility when working with new composites.
- **Materials genome:** Advanced materials are developed from a novel understanding of compounds at a molecular level through applied physics, material science and chemistry.
- **New battery storage technologies**: As mobility becomes a necessity for consumer and industrial products few cross-cutting technologies have the potential to impact as many advanced industries as next-generation battery technology.
- **Organic tissue engineering:** Tissue engineering is the process of recreating human or animal complex organ functions outside of the body. Tissue engineering has the potential to redefine pharmaceutical and life sciences industries by allowing for drug testing outside of living subjects.
- **Smart automation:** Automation and advanced robotics allow for greater speed, consistency and complexity within the production process.

Sources: President's Council of Advisors on Science and Technology, "Competitive Advantage in Advanced Manufacturing"; McKinsey Global Institute, "Disruptive Technologies: Advances that Will Transform Life, Business, and the Global Economy."

Automotive Research, to see if that forum can yield meaningful ways to coordinate R&D activities and so scale them up in the South. With a number of Southern states currently moving to boost automotive R&D, SARA could help Tennessee better leverage regional research institutions such as South Carolina's International Center for Automotive Research (I-CAR) to address the technical needs of firms and universities in Tennessee. And yet, bootstrapping technology development from neighboring states will not suffice as a strategy for enhancing the state's technology capacities. Accordingly, the state should begin now to step up its own efforts to build its own technology expertise in fields relevant to its particular AIs.

Fortuitously, the state possesses two ideal forums for advancing the needed technology drive. One of these is the UT's campaign to become a top-25 public research university. The other is the UT-ORNL Governor's Chair Program, which seeks to attract exceptionally accomplished researchers from around the world to boost joint research efforts in biological science, neutron science, computational science, and advanced materials. Each of these initiatives is pointed in the right direction as increasing R&D activity and ultimately tech transfer will always be tied to increases in the quality of the state's researchers. However, each program could be deployed even more strategically to the state's necessary industrial agenda if it were tuned even more toward building the state's AI capacities. In each case, an intensified focus on AI-relevant

translational research and an accelerated investment program could be transformational. This summer's hiring of Sudarsanam Suresh Babu as the Governor's Chair for Advanced Manufacturing moved in exactly the needed direction by bringing to Tennessee a nationally known researcher with deep basic and applied research involvement in highly AI-relevant metals, materials, and processing topics. The next task is to accelerate the investments and maintain the focus over time.

The federal government must also realign policy to better support Tennessee's advanced industries

The state of Tennessee is recommitting itself to advancing the state's automotive industry (and other AIs) through partnerships and initiatives that catalyze industry development, enlarge the AI skills workforce, and upgrade the state's innovation assets. The state's congressional delegation also needs to be involved. Notwithstanding the current paralysis in Washington, Tennessee members should push for federal policies that set a platform for growth and support the goals of the renewed industry-state partnership.

Federal policy matters because the federal government plays a large role in setting the platform for AI growth. Federal lawmakers set much of the tax and trade environment within which states' AI firms operate. Federal policy can help or hinder collaborative problem solving on regional supply-chain issues, workforce development, and innovation. And the federal government can and does enable sector growth directly through its investments—whether in workforce development or basic and applied R&D.

As such, the Tennessee congressional delegation—in concert with industry and state government—should reinvigorate its efforts in Washington to further develop the state's AI sector. Priorities emerge from each of the three strategic themes identified by this report:

Drive Continuous Industry Development

A number of outstanding issues must be addressed in order to improve the basic competitive standing of advanced industries, whether in Tennessee or elsewhere. From work on the basic tax environment to upgrades of the nation's supply-chain supports and trade stances, progress on these priority items will help industry and state government work together to advance the state's AI and auto-sector strength. On this front the state needs Washington to:

- **Reform the U.S. corporate income tax rate** (currently the highest among OECD countries) to bring the effective rate in line with competitors as part of a comprehensive tax code overhaul.[6]
- **Institute an investment tax credit for new capital equipment and software** and reduce the federal tax depreciation schedule so firms can expense new technology and capital equipment within the first year[7]
- **Fund and expand programs that catalyze regional AI cluster initiatives,** beginning with the Investing in Manufacturing Communities Partnership[8]
- **Better support and align export promotion programs** to streamline multi-jurisdictional efforts and encourage public-private partnerships on regional export plans[9]
- **Promote trade liberalization and expanded market access** with major auto-producing and auto-buying countries to address tariff and non-tariff trade barriers. In particular, the United States should quickly negotiate and sign the Trans-Pacific Partnership Agreement and the Transatlantic Trade and Investment Partnership
- **Seek program harmonization** across the federal and state agencies that oversee the activities of AI supply chains

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Beyond the basics of competitive efficiency, the success of the auto industry—and all AIs—hinges upon a skilled workforce and a reliable talent pipeline. The federal government should therefore support states and regions in their

The federal government must also realign policy (continued)

efforts to maintain and replenish a technically proficient workforce. Along these lines, Tennessee needs the federal government to:

- **Align education and workforce policy reforms** to better link occupational skills training to K-12 and higher education in order to develop a more coherent education and training pipeline that leads from high school into postsecondary education and the labor market[10]
- **Create a "Race to the Shop" competition** to reward bottom-up, business-led creativity in reforming and modernizing the regional delivery of federally funded workforce education and skills training for AIs[11]
- **Support employer acceptance and use of industry-recognized certifications.** Certifications, such as those endorsed by the National Association of Manufacturers, can be a powerful indicator of what a person knows and can do, but to be successful a critical mass of employers must first recognize and incorporate the certifications into their HR practices
- **Support STEM and career and technical education initiatives** that bridge high school and postsecondary education with strong employer engagement to better equip graduates for the labor market[12]
- **Expand and coordinate initiatives to inspire and excite elementary and high school students about STEM** subjects, both in school and through individualized and group experiences outside the classroom[13]

Commit to Innovation at All Levels of the Supply Chain

Finally, Tennessee's auto community needs the federal government to recommit to innovation. As innovation becomes an ever more critical precursor to advantage, the state's congressional delegation should focus intensely on stepping up federal investments in basic and applied R&D and promoting the rapid flow of technical gains into the private sector. To that end the federal government should:

- **Invest in R&D for cross-cutting AI technologies** by moving to double the research budgets of three key science agencies over the next decade: the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology. In implementing this agenda Congress should make sure that funding flows toward key AI- and auto-related technology issues such as materials science, advanced sensing, and industrial robotics[14]
- **Scale up the National Network for Manufacturing Innovation (NNMI) and create similar applied research consortia on engineering topics.** Of almost equal importance to enlarging the scale of the nation's R&D investments is the need for channeling more of the work through more applied, translational formats that bring universities and industry into closer collaboration in U.S. regions. Scaling up the NNMI effort and establishing similar multi-sectoral regional centers to work on engineering problems of direct concern to industry would fill a serious gap in the nation's innovation system. Furthermore, securing such a center for Tennessee could prove transformative for the state's AI sector[15]
- **Increase funding for the Manufacturing Extension Partnership (MEP) and reorganize MEP as a one-stop shop for all federal SME support programs** by coordinating the currently dispersed and numerous federal programs tasked with financial support, work force skills, business development, and technology diffusion to the country's SME manufacturers[16]
- **Facilitate and incentivize national labs' interactions with regional industry clusters and SMEs,** in part by adjusting the strictures of small-scale contracts and broader Work-For-Others agreements. This action will be critical if Tennessee is to better leverage the technical expertise of ORNL
- **Make permanent and expand the R&E tax credit** by increasing the credit's generosity, making clear that process R&D qualifies for the credit, and creating a collaborative credit for multi-stakeholder research.[17] All of these changes are necessary to stimulate more private-sector R&D activity in Tennessee and to reflect the intensified, increasingly collaborative nature of the AI innovation game. A further worthwhile expansion would make expenditures on employees eligible expenses for the R&D credit

* * *

In sum, while industry will determine Tennessee's automotive destiny government has a role to play in addressing a number of market weaknesses. Most notably, state government must engage to catalyze more vibrant supply-chain exchanges, facilitate more responsive problem solving on workforce development, and build the state's AI technology enterprise. To similar ends, the state's congressional delegation should push for federal policies that set a platform for growth and support the goals of the industry-state partnership at home.

STATE AGENDA

$ = Little to no cost	**$$** = Low cost	**$$$** = Moderate cost	**$$$$** = High cost

Drive Continuous Industry Development

Focus on groups of firms, SMEs, and the supply chain	**$**
Name a sector lead in state government to spearhead automotive industry development	**$$**
Catalyze the creation of a robust automotive industry association	**$$$**
Emphasize international engagement, both by "doubling down" on export promotion and linking export and FDI promotion	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Create an AI skills champion	**$$**
Establish an AI skills challenge grant program	**$$$**
Expand access to work-based learning opportunities	**$$**

Commit to Innovation at All Levels of the Supply Chain

Prioritize technology development and diffusion	**$**
Encourage private-sector innovative activity	**$$-$$$$**
Encourage technology transfer from UT and ORNL	**$$-$$$**
Continue building the advanced industry knowledge base	**$$$$**

FEDERAL AGENDA

$ = Little to no cost	**$$** = Low cost	**$$$** = Moderate cost	**$$$$** = High cost

Drive Continuous Industry Development

Reform the U.S. corporate income tax rate	**$$$-$$$$**
Institute an investment tax credit for new capital equipment	**$$-$$$$**
Fund an expand programs that catalyze regional AI cluster initiatives	**$$**
Better support and align export promotion programs	**$$**
Promote trade liberalization and expanded market access	**$$**
Seek program harmonization	**$**

Develop the Workforce Pipeline to Strengthen Tennessee's AI Skills Base

Align education and workforce policy reforms	**$**
Create a "Race to the Shop" competition	**$$**
Support employer acceptance and use of industry-recognized certifications	**$$**
Support STEM and career and technical education initiatives	**$$$**
Expand and coordinate initiatives to inspire and excite elementary and high school students about STEM	**$**

Commit to Innovation at All Levels of the Supply Chain

Invest in R&D for cross-cutting AI technologies	**$$$$**
Scale up the National Network for Manufacturing Innovation (NNMI) and create similar translational research consortia on engineering topics	**$$$**
Increase funding for the Manufacturing Extension Partnership (MEP) and reorganize MEP as a one-stop-shop for all federal SME support programs	**$$-$$$**
Facilitate and incentivize national labs' interactions with regional industry clusters and SMEs	**$$**
Make permanent and expand the R&E tax credit	**$$$$**

IX. CONCLUSION

Ultimately, the data and analyses presented here inspire both confidence and disquiet. Without doubt, Tennessee's significant automotive production sector is well positioned in many respects. Not only do the reported trend lines confirm that the state sector has weathered the worst economic disruption in 70 years but they also argue that the industry has emerged from the crisis with new momentum.

Most notably, the state industry has actually *increased* its share of the North American auto-production enterprise during this shock decade and now ranks first in the South for the size of its supply chain.

In short, this strong automotive state—leaner than it was before the crisis—continues to present a compelling value-proposition in the global automotive industry.

With that said, though, key elements of this analysis should prompt unease. New entrants in the global marketplace, converging wages across auto production sites, and the rise of Mexico as the latest and most formidable low-cost challenger in North American auto manufacturing mean that Tennessee's longstanding cost-based appeal will likely prove insufficient going forward.

To be sure, cost-based appeals will remain a prerequisite for regional and state advantage. However, such factors will need to be complemented in the next half-decade with the operational excellence provided by local synergies, the ability to win on workforce development, and the game-changing power of product and process innovation. Tennessee has yet to establish true superiority on any of these factors, although it possesses genuine strengths in each.

Today and going forward, Tennessee needs a new surge of foresight and self-assertion aimed at preparing its pioneering production capability to compete in new ways based on new determinants of competitive advantage.

Mastering the current moment, in sum, will require new thinking and urgent action—and will challenge all stakeholders to act differently. However, the state that went to Japan to change its future has done this before. It can do it again.

APPENDIX A. METHODOLOGY

Defining the automotive industry

Brookings brought a novel establishment-based methodology to this project, because only such a high-resolution approach could generate the sort of granular information necessary for truly understanding the automotive industry as it exists in the real economy, and for informing strategy and policy to advance it.

The automotive industry consists of far more than the three 4-digit NAICS codes that conventional approaches utilize for analysis. Instead of producing a single product, the industry integrates a great variety of products onto a single platform and into a single system: the automobile. As such, the industry's elongated supply chain includes establishments producing everything from tires (NAICS 3262) to windshields (NAICS 3272) to semiconductors (NAICS 3344). In fact, according to the Bureau of Economic Analysis, in 2011 the motor vehicle industry itself consumed a massive $393 billion worth of other industries' output.

Accordingly, given the overly narrow scope of NAICS-based approaches, Brookings set out to build a custom establishment-by-establishment dataset of the automotive industry, relying on trusted third-party industry intelligence providers to identify the universe of companies and establishments engaged in the North American automotive industry supply chain as their primary business activity. This appendix explains the methodology that was used to build the Brookings North American automotive industry database.

Creating Brookings' automotive industry database

Brookings adopted a unique establishment-based approach to measure the automotive industry in Tennessee and throughout North America. This methodology required building a dataset from the bottom up by identifying every physical business establishment—defined as a single discrete location of production—involved in producing goods and services for the automotive industry.

In order to identify every business establishment in North America producing for the automotive industry, Brookings turned to the leading third-party industry intelligence providers MarkLines and ELM Analytics. These two companies provide directories of all automotive industry production facilities and supplier establishments in North America. Brookings obtained each directory in its entirety and together they form the foundation of Brookings' dataset.

To complete the process of identifying the full universe of automotive production-related establishments in North America, Brookings turned to Hoover's Dun & Bradstreet database. Brookings took a number of steps to ensure that it created a comprehensive and accurate dataset.

First, Brookings matched all establishment records from ELM Analytics and MarkLines to corresponding records in D&B.

Then, Brookings downloaded all establishments in D&B whose primary activity was classified as one of three auto-exclusive NAICS industry codes: 3361 (motor vehicle manufacturing), 3362 (motor vehicle body and trailer manufacturing, and 3363 (motor vehicle parts manufacturing).

Brookings subsequently conducted the same exercise for a larger list of detailed eight-digit Standard Industrial Classification (SIC) codes exclusively related to automotive production. A list of those codes—identified via keyword searches—is provided below in Table 4.

Next, Brookings manually searched D&B by automaker name to ensure that all establishments of major companies had been captured.

Finally, Brookings downloaded all establishments in the Hoover's Auto Family, an automotive industry directory produced by Hoover's that is similar to MarkLines and ELM.

After duplicates were removed, the final establishment dataset with 31,605 unique records from the United States, Canada, and Mexico was complete. D&B provided the establishment characteristics—such as job estimates and NAICS and SIC code classifications—used in the analysis, except in the few cases noted below.

Brookings designed its methodology to provide as complete and accurate a picture of the automotive industry in North America as possible. However, this method is only capable of providing a snapshot of a dynamic and ever-changing industry. Establishments open, close, and change hands, just as employment counts rise and fall. Given the nature of the task at hand, and the reality that D&B data is compiled via telephonic surveys of companies and reported by humans, the final database inevitably contains error. Brookings took a number of steps to minimize that error.

First, to mitigate selection bias Brookings utilized the most authoritative third-party industry datasets that had complete North American coverage. Brookings was unable to augment its database with single-state industry directories—like that kept by the State of Tennessee's Department of Economic and Community Development, for example—because such asymmetric contributions would have compromised comparability across geographies by favorably increasing establishment and so jobs numbers for only one region.

To correct for any employment omissions or potentially faulty estimates in D&B's data, Brookings automatically substituted ELM Analytics employment numbers—themselves vetted for accuracy by the company—where available. Brookings continued to vet any outlying observations using company websites, LexisNexis news reports, and satellite imagery to judge establishment size. Brookings imputed average employment in an establishment's industry code for any remaining establishment whose employment estimates were suppressed by D&B and not available from ELM.

Classifying automotive industry establishments

Brookings assigned each establishment in its database to one of four categories: automakers, suppliers, business and professional services providers, and other motor vehicle and related production manufacturers. The supplier category was further broken out into six segments of activity corresponding to sub-systems of the automobile: basic inputs and materials; body and interior; chassis (including wheels and tires); electronics; miscellaneous parts and components; and powertrain (including engines). See Table 1 for parts classifications.

Table 1: Brookings' automotive industry establishment classification scheme

Automaker (Production and Services)			
Business & Professional Services			
Other Motor Vehicle & Machinery Production		**Machinery**	
		Motor Vehicles	
Supplier Network	Basic Inputs	Metal Inputs	Fabricated Metal Inputs
			Primary Metal Inputs
		Non-Metal Inputs	Chemical & Fuel Inputs
			Clay & Cement Inputs
			Packaging Materials
			Plastic & Rubber Inputs
			Textile Inputs
	Body & Interior	Body	Automotive & Miscellaneous Body
			Truck Body
		Interior & Windows	Fabrics, Trimmings, & Seats
			Lighting
			Windows & Mirrors
	Chassis	Chassis Frame & Trailers	Chassis Frame
			Trailers
		Steering, Suspension, & Brakes	Brakes
			Steering
			Suspension
		Wheels & Tires	Tires
			Wheels
	Electronics	Electrical, Ignition, & Battery Equipment	Battery
			Ignition & Electrical Equipment
		Instruments, Sensors, & Controls	Environmental Controls
			Instruments, Computers, & Sensors
	Parts & Components		Hardware, Forgings, Joints, & Bearings
			Miscellaneous Parts
			Synthetic Parts
	Powertrain	Drivetrain	Axles
			Exhaust
			Fuel System
		Engine	Electric Motors
			Engine Cooling & Lubrication
			Engine Sets
			Miscellaneous Engine Parts
			Valves, Shafts, Rods, & Cylinders
		Transmission	Clutches, Shafts, & Controls
			Gearboxes & Converters

Establishments were classified as automakers if their global parent company registered as one of the top global automakers (see Table 2 for list of top automakers). Establishments were identified as suppliers if MarkLines and ELM classified them as such and/or if the associated eight-digit primary SIC code matched one of the codes off of which Brookings constructed the supplier segmentation scheme. Establishments not falling into the supplier network were classified as business and professional services providers if they were services firms or as other motor vehicle and related production manufacturers if they produced manufactures that fell outside of the supplier segmentation scheme. All establishments not captured by this automated process were manually sorted into categories and segments by the Brookings team based on available information, or rejected from the dataset as erroneous identification.

Table 2: Top global automaker parent companies

Continent	Country	Automaker	DUNS (unique identifiers from D&B)
North America	United States	Ford	001344746
		General Motors	832447812
		Navistar	161984646
		PACCAR	048341267
		Tesla	148284255
		THINK	830402777
		ZAP	877218057
Europe	France	Peugeot	275262145
	Germany	BMW	315369934
		Daimler	498999044
		Volkswagen	315016295
	Italy	Fiat	428003065, 415976146
	Sweden	Scania	354678906
		Volvo	144304094, 353952559, 421261100, 849152061
Asia	China	Chang'an	530953090
	India	Tata	602990012, 650048044, 650664634
	Japan	Fuji	133357389, 690550900
		Honda	690566815
		Isuzu	167306310, 690542048
		Mazda	690535604
		Mitsubishi	690543699, 690543756, 690546460, 690552633, 690574991
		Nissan	690542212
		Suzuki	690557988
		Toyota	205631443, 690537790, 690564737, 690911185, 691239750
	Republic of Korea	Hyundai	687746024
		Kia	687737585, 828808480

Checking the Brookings database

To reality-check its database and verify the accuracy of its method, Brookings compared its findings to those of leading studies in the field. Comparison studies included: CAR (2002), Census (2002), Klier and Rubenstein (2008), and Merrill Lynch (2007).

Given that Brookings specifically designed its study to be the most comprehensive North American analysis of the automotive industry and its supply chain to date, few studies exist for exact comparison on total employment or establishment terms. Brookings fully expected its method to yield one of the highest direct counts on each in the field, and it has. Given that, Brookings tested for robustness by comparing the share of supplier establishments in each segment in its dataset to the share of supplier establishments in each segment in the leading benchmark study, Klier and Rubenstein's 2008 book, *Who Really Made Your Car?*

As shown below in Table 3, the share of establishments in each supplier segment in Brookings' dataset and in Klier and Rubenstein's dataset is highly correlated with a 97.5 percent fit. (Only U.S. suppliers were included in this robustness exercise.) Because Klier and Rubenstein's segmentation scheme served as a model for Brookings' work, this high correlation boosted confidence that Brookings' methodology scaled but did not distort Klier and Rubenstein's precedent. Although the fit with other listed studies is lower, Brookings' faith in their appropriateness as the ultimate benchmark is lower too. What is more, the distribution of employees across supplier segments in Brookings' database correlates highly with that reported in Bureau of Labor Statistics data from 2007, as cited in Klier and Rubenstein.

Table 3: Comparing the Brookings database to other studies

	Share of Establishments in Parts Group Employment					Share of Employment	
Correlation with Brookings		97.5%	69.7%	69.6%	33.8%	89.5%	
Source	**Brookings, 2013**	**Klier & Rubenstein, 2008**	**Merrill Lynch, 2007**	**CAR, 2002**	**Census, 2002**	**BLS, 2007**	**Brookings, 2013**
Body & Interior	31.3%	29%	39%	34%	25%	31.8%	31.0%
Chassis	19.5%	19%	18%	15%	9%	11.4%	16.3%
Electronics	10.8%	15%	18%	11%	21%	12.5%	15.5%
Parts & Components	16.5%	16%	0%	0%	18%	23.6%	18.7%
Powertrain	21.8%	22%	36%	40%	27%	20.7%	18.5%
Total Employment						673,000	1,722,415

**The Basic Input suppliers were distributed amongst the following: Body & Interior includes Fabricated Metal Inputs, Primary Metal Inputs, Packaging Materials, and Textile Inputs. Powertrain includes Chemical & Fuel Inputs. Chassis includes Clay & Cement Inputs and Plastic & Rubber Inputs.*

Table 4: Complete list of automotive industry SIC codes used to identify establishments and segment the supply chain

SIC8	SIC8 Description	Parts Category
26310401	Automobile board	Automotive & Miscellaneous Body
34650000	Automotive stampings	Automotive & Miscellaneous Body
34659900	Automotive stampings, nec	Automotive & Miscellaneous Body
34659901	Body parts, automobile: stamped metal	Automotive & Miscellaneous Body
34659902	Fenders, automobile: stamped or pressed metal	Automotive & Miscellaneous Body
34659904	Moldings or trim, automobile: stamped metal	Automotive & Miscellaneous Body
34659905	Tops, automobile: stamped metal	Automotive & Miscellaneous Body
34699902	Automobile license tags, stamped metal	Automotive & Miscellaneous Body
34710108	Rechroming auto bumpers	Automotive & Miscellaneous Body
37110102	Automobile bodies, passenger car, not including engine, etc.	Automotive & Miscellaneous Body
37130210	Hearse bodies	Automotive & Miscellaneous Body
37130214	Van bodies	Automotive & Miscellaneous Body
37130202	Automobile wrecker truck bodies	Automotive & Miscellaneous Body
37110000	Motor vehicles and car bodies	Automotive & Miscellaneous Body
37140300	Motor vehicle body components and frame	Automotive & Miscellaneous Body
37140301	Bumpers and bumperettes, motor vehicle	Automotive & Miscellaneous Body
37140303	Hoods, motor vehicle	Automotive & Miscellaneous Body
37140306	Sun roofs, motor vehicle	Automotive & Miscellaneous Body
37140307	Tops, motor vehicle	Automotive & Miscellaneous Body
37140308	Wind deflectors, motor vehicle	Automotive & Miscellaneous Body
37149910	Winter fronts, motor vehicle	Automotive & Miscellaneous Body
35370203	Cabs, for industrial trucks and tractors	Truck Body
37130213	Utility truck bodies	Truck Body
37149911	Pickup truck bed liners	Truck Body
25310301	Cabs, for off-highway trucks	Truck Body
37130000	Truck and bus bodies	Truck Body
37130100	Truck bodies and parts	Truck Body
37130101	Truck beds	Truck Body
37130102	Truck bodies (motor vehicles)	Truck Body
37130103	Truck cabs, for motor vehicles	Truck Body
37130104	Truck tops	Truck Body
37130200	Specialty motor vehicle bodies	Truck Body
37130201	Ambulance bodies	Truck Body
37130203	Beverage truck bodies	Truck Body
37130204	Bus bodies (motor vehicles)	Truck Body
37130207	Dump truck bodies	Truck Body
37130208	Farm truck bodies	Truck Body
37130209	Garbage, refuse truck bodies	Truck Body
37130211	Stake, platform truck bodies	Truck Body
37130212	Tank truck bodies	Truck Body
22110602	Automotive fabrics, cotton	Fabrics, Trimmings, & Seats
22110607	Seat cover cloth, automobile: cotton	Fabrics, Trimmings, & Seats
22210601	Automotive fabrics, manmade fiber	Fabrics, Trimmings, & Seats
22730100	Aircraft and automobile floor coverings	Fabrics, Trimmings, & Seats
22730102	Automobile floor coverings, except rubber or plastic	Fabrics, Trimmings, & Seats
22990202	Automotive felts	Fabrics, Trimmings, & Seats
23969901	Automotive trimmings, fabric	Fabrics, Trimmings, & Seats
23990404	Seat belts, automobile and aircraft	Fabrics, Trimmings, & Seats

SIC8	SIC8 Description	Parts Category
23999910	Seat covers, automobile	Fabrics, Trimmings, & Seats
25310303	Seats, automobile	Fabrics, Trimmings, & Seats
34999904	Automobile seat frames, metal	Fabrics, Trimmings, & Seats
37519904	Saddles and seat posts, motorcycle and bicycle	Fabrics, Trimmings, & Seats
36470100	Motor vehicle lighting equipment	Lighting
36470101	Automotive lighting fixtures, nec	Lighting
36470102	Clearance lamps and reflectors, motor vehicle	Lighting
36470103	Dome lights, automotive	Lighting
36470104	Flasher lights, automotive	Lighting
36470105	Headlights (fixtures), vehicular	Lighting
36470106	Marker lamps, motor vehicle	Lighting
36470107	Parking lights, automotive	Lighting
36470108	Spotlights, motor vehicle	Lighting
36470109	Taillights, motor vehicle	Lighting
36479900	Vehicular lighting equipment, nec	Lighting
36479906	Motorcycle lamps	Lighting
37140403	Directional signals, motor vehicle	Lighting
32310201	Mirrors, truck and automobile: made from purchased glass	Windows & Mirrors
30899924	Windshields, plastics	Windows & Mirrors
32310407	Windshields, glass: made from purchased glass	Windows & Mirrors
37140309	Windshield frames, motor vehicle	Windows & Mirrors
37110105	Chassis, motor vehicle	Chassis Frame
37140302	Frames, motor vehicle	Chassis Frame
37519901	Frames, motorcycle and bicycle	Chassis Frame
37149909	Trailer hitches, motor vehicle	Trailers
37150000	Truck trailers	Trailers
37159900	Truck trailers, nec	Trailers
37159901	Bus trailers, tractor type	Trailers
37159904	Semitrailers for truck tractors	Trailers
37159905	Trailer bodies	Trailers
37159907	Truck trailer chassis	Trailers
37929901	Automobile house trailer chassis	Trailers
37929903	Camping trailers and chassis	Trailers
37929904	House trailers, except as permanent dwellings	Trailers
37929906	Tent-type camping trailers	Trailers
37929907	Trailer coaches, automobile	Trailers
37929908	Travel trailer chassis	Trailers
37990100	Trailers and trailer equipment	Trailers
37990101	Automobile trailer chassis	Trailers
37990102	Boat trailers	Trailers
37990103	Horse trailers, except fifth-wheel type	Trailers
37990105	Trailer hitches	Trailers
32920401	Brake linings, asbestos	Brakes
37140500	Motor vehicle brake systems and parts	Brakes
37140501	Air brakes, motor vehicle	Brakes
37140502	Brake drums, motor vehicle	Brakes
37140503	Vacuum brakes, motor vehicle	Brakes
36210300	Control equipment for electric buses and locomotives	Steering
36210301	Control equipment for buses or trucks, electric	Steering
37140124	Tie rods, motor vehicle	Steering
37140305	Steering mechanisms, motor vehicle	Steering
37140600	Motor vehicle steering systems and parts	Steering

SIC8	SIC8 Description	Parts Category
37140601	Hydraulic fluid power pumps, for auto steering mechanism	Steering
37140602	Power steering equipment, motor vehicle	Steering
37519903	Handle bars, motorcycle and bicycle	Steering
34930101	Automobile springs	Suspension
34930104	Leaf springs: automobile, locomotive, etc.	Suspension
37140201	Anti-sway devices, motor vehicle	Suspension
37140304	Shock absorbers, motor vehicle	Suspension
30110103	Automobile inner tubes	Tires
30110106	Motorcycle inner tubes	Tires
30110107	Truck or bus inner tubes	Tires
30110203	Automobile tires, pneumatic	Tires
30110206	Motorcycle tires, pneumatic	Tires
30110207	Truck or bus tires, pneumatic	Tires
30110300	Tire and inner tube materials and related products	Tires
37140701	Tire valve cores	Tires
33120902	Wheels, locomotive and car: iron and steel	Wheels
34659903	Hub caps, automobile: stamped metal	Wheels
37140700	Motor vehicle wheels and parts	Wheels
37140702	Wheel rims, motor vehicle	Wheels
37140703	Wheels, motor vehicle	Wheels
37149904	Fifth wheel, motor vehicle	Wheels
36940102	Battery charging generators, automobile and aircraft	Battery
36940103	Generators, automotive and aircraft	Battery
36940104	Motor generator sets, automotive	Battery
36940105	Voltage regulators, automotive	Battery
36940201	Distributors, motor vehicle engine	Battery
36949900	Engine electrical equipment, nec	Battery
36949901	Armatures, automotive	Battery
36949903	Battery cable wiring sets for internal combustion engines	Battery
37140400	Motor vehicle electrical equipment	Ignition & Electrical Equipment
37140401	Automotive wiring harness sets	Ignition & Electrical Equipment
36940000	Engine electrical equipment	Ignition & Electrical Equipment
36940101	Alternators, automotive	Ignition & Electrical Equipment
36940202	Harness wiring sets, internal combustion engines	Ignition & Electrical Equipment
36949902	Automotive electrical equipment, nec	Ignition & Electrical Equipment
36949904	Breaker point sets, internal combustion engine	Ignition & Electrical Equipment
32649907	Spark plugs, porcelain	Ignition & Electrical Equipment
35190202	Engine starters, pneumatic	Ignition & Electrical Equipment
36940200	Ignition apparatus and distributors	Ignition & Electrical Equipment
36940203	Ignition apparatus, internal combustion engines	Ignition & Electrical Equipment
36940204	Ignition coils, automotive	Ignition & Electrical Equipment
36940205	Ignition systems, high frequency	Ignition & Electrical Equipment
36940206	Motors, starting: automotive and aircraft	Ignition & Electrical Equipment
36940207	Spark plugs, for internal combustion engines	Ignition & Electrical Equipment
35850102	Air conditioning, motor vehicle	Environmental Controls
37140402	Defrosters, motor vehicle	Environmental Controls
37140404	Heaters, motor vehicle	Environmental Controls
37140405	Horns, motor vehicle	Environmental Controls
37140408	Windshield wiper systems, motor vehicle	Environmental Controls
37140409	Wipers, windshield, motor vehicle	Environmental Controls
37149901	Air conditioner parts, motor vehicle	Environmental Controls
37140406	Instrument board assemblies, motor vehicle	Instruments, Computers, & Sensors

SIC8	SIC8 Description	Parts Category
37140407	Thermostats, motor vehicle	Instruments, Computers, & Sensors
38240116	Vehicle tank meters	Instruments, Computers, & Sensors
38240300	Vehicle instruments	Instruments, Computers, & Sensors
38240301	Odometers	Instruments, Computers, & Sensors
38240302	Speed indicators and recorders, vehicle	Instruments, Computers, & Sensors
38240303	Speedometers	Instruments, Computers, & Sensors
38240304	Tachometer, centrifugal	Instruments, Computers, & Sensors
38249901	Controls, revolution and timing instruments	Instruments, Computers, & Sensors
38250102	Automotive ammeters and voltmeters	Instruments, Computers, & Sensors
38250107	Internal combustion engine analyzers, to test electronics	Instruments, Computers, & Sensors
38250235	Tachometer generators	Instruments, Computers, & Sensors
38290100	Aircraft and motor vehicle measurement equipment	Instruments, Computers, & Sensors
38290106	Gauges, motor vehicle: oil pressure, water temperature	Instruments, Computers, & Sensors
38290108	Instrument board gauges, automotive: computerized	Instruments, Computers, & Sensors
38290109	Oil pressure gauges, motor vehicle	Instruments, Computers, & Sensors
38290114	Water temperature gauges, motor vehicle	Instruments, Computers, & Sensors
37149907	Sanders, motor vehicle safety	Instruments, Computers, & Sensors
33579904	Automotive wire and cable, except ignition sets: nonferrous	Instruments, Computers, & Sensors
34290300	Motor vehicle hardware	Hardware, Forgings, Joints, & Bearings
34639903	Automotive forgings, nonferrous	Hardware, Forgings, Joints, & Bearings
37140204	Ball joints, motor vehicle	Hardware, Forgings, Joints, & Bearings
37140205	Bearings, motor vehicle	Hardware, Forgings, Joints, & Bearings
37140213	Universal joints, motor vehicle	Hardware, Forgings, Joints, & Bearings
30520102	Automobile hose, rubber	Synthetic Parts
30520201	Automobile hose, plastic	Synthetic Parts
30619902	Automotive rubber goods (mechanical)	Synthetic Parts
30691400	Rubber automotive products	Synthetic Parts
30691402	Rubber covered motor mounting rings (rubber bonded)	Synthetic Parts
30899926	Automotive parts, plastic	Synthetic Parts
37140202	Axle housings and shafts, motor vehicle	Axles
37140203	Axles, motor vehicle	Axles
37140210	Rear axle housings, motor vehicle	Axles
37149908	Third axle attachments or six wheel units for motor vehicles	Axles
37140104	Cleaners, air, motor vehicle	Exhaust
37140109	Exhaust systems and parts, motor vehicle	Exhaust
37140117	Manifolds, motor vehicle	Exhaust
37140118	Mufflers (exhaust), motor vehicle	Exhaust
75339901	Catalytic conversion	Exhaust
37140110	Filters: oil, fuel, and air, motor vehicle	Fuel System
37140111	Fuel pipes, motor vehicle	Fuel System
37140112	Fuel pumps, motor vehicle	Fuel System
37140113	Fuel systems and parts, motor vehicle	Fuel System
37140114	Gas tanks, motor vehicle	Fuel System
37140121	Propane conversion equipment, motor vehicle	Fuel System
36210108	Motors, electric	Electric Motors
36210200	Electric motor and generator auxillary parts	Electric Motors
37140119	Oil pump, motor vehicle	Engine Cooling & Lubrication
37140120	Oil strainers, motor vehicle	Engine Cooling & Lubrication
37140116	Lubrication systems and parts, motor vehicle	Engine Cooling & Lubrication
37140122	Radiators and radiator shells and cores, motor vehicle	Engine Cooling & Lubrication
37140125	Water pump, motor vehicle	Engine Cooling & Lubrication
35199900	Internal combustion engines, nec, nec	Engine Sets

SIC8	SIC8 Description	Parts Category
35199902	Gasoline engines	Engine Sets
37140123	Rebuilding engines and transmissions, factory basis	Engine Sets
35190000	Internal combustion engines, nec	Engine Sets
35190102	Engines, diesel and semi-diesel or dual-fuel	Engine Sets
34620300	Automotive and internal combustion engine forgings	Miscellaneous Engine Parts
34620302	Internal combustion engine forgings, ferrous	Miscellaneous Engine Parts
37519902	Gears, motorcycle and bicycle	Miscellaneous Engine Parts
37140208	Gears, motor vehicle	Miscellaneous Engine Parts
35190200	Parts and accessories, internal combustion engines	Miscellaneous Engine Parts
35190203	Governors, diesel engine	Miscellaneous Engine Parts
35190204	Governors, pump, for diesel engines	Miscellaneous Engine Parts
37140101	Acceleration equipment, motor vehicle	Miscellaneous Engine Parts
37140115	Governors, motor vehicle	Miscellaneous Engine Parts
35999905	Crankshafts and camshafts, machining	Valves, Shafts, Rods, & Cylinders
37140102	Camshafts, motor vehicle	Valves, Shafts, Rods, & Cylinders
37140106	Crankshaft assemblies, motor vehicle	Valves, Shafts, Rods, & Cylinders
34620301	Automotive forgings, ferrous: crankshaft, engine, axle, etc.	Valves, Shafts, Rods, & Cylinders
37140107	Cylinder heads, motor vehicle	Valves, Shafts, Rods, & Cylinders
37140103	Choker rods, motor vehicle	Valves, Shafts, Rods, & Cylinders
37140105	Connecting rods, motor vehicle engine	Valves, Shafts, Rods, & Cylinders
35920102	Valves, engine	Valves, Shafts, Rods, & Cylinders
37140100	Motor vehicle engines and parts	Clutches, Shafts, & Controls
32920402	Clutch facings, asbestos	Clutches, Shafts, & Controls
35689902	Collars, shaft (power transmission equipment)	Clutches, Shafts, & Controls
37140206	Clutches, motor vehicle	Clutches, Shafts, & Controls
37140207	Drive shafts, motor vehicle	Clutches, Shafts, & Controls
35949901	Hydrostatic drives (transmissions)	Clutches, Shafts, & Controls
37140209	Power transmission equipment, motor vehicle	Clutches, Shafts, & Controls
37140211	Transmission housings or parts, motor vehicle	Clutches, Shafts, & Controls
37140108	Differentials and parts, motor vehicle	Gearboxes & Converters
37140200	Motor vehicle transmissions, drive assemblies, and parts	Gearboxes & Converters
37140212	Transmissions, motor vehicle	Gearboxes & Converters
15419911	Truck and automobile assembly plant construction	Industrial Machinery
35590300	Automotive related machinery	Industrial Machinery
35590301	Automotive maintenance equipment	Industrial Machinery
35590302	Degreasing machines, automotive and industrial	Industrial Machinery
35590305	Wheel balancing equipment, automotive	Industrial Machinery
35699914	Robots, assembly line: industrial and commercial	Industrial Machinery
37110100	Automobile assembly, including specialty automobiles	Automobiles
37110106	Hearses (motor vehicles), assembly of	Automobiles
37110107	Patrol wagons (motor vehicles), assembly of	Automobiles
37110108	Station wagons (motor vehicles), assembly of	Automobiles
37110109	Taxicabs, assembly of	Automobiles
37110304	Scout cars (motor vehicles), assembly of	Automobiles
76929901	Automotive welding	Automobiles
37110400	Bus and other large specialty vehicle assembly	Buses
37110402	Buses, all types, assembly of	Buses
37110405	Motor buses, except trackless trollies, assembly of	Buses
37430204	Trackless trolley buses	Buses
37110104	Cars, electric, assembly of	Electric Vehicles
35310617	Trucks, off-highway	Industrial Vehicles
35370000	Industrial trucks and tractors	Industrial Vehicles

SIC8	SIC8 Description	Parts Category
35370200	Trucks, tractors, loaders, carriers, and similar equipment	Industrial Vehicles
35370204	Cars and trucks, for industrial mining	Industrial Vehicles
35370217	Truck trailers, used in plants, docks, terminals, etc.	Industrial Vehicles
35370218	Trucks: freight, baggage, etc.: industrial, except mining	Industrial Vehicles
37110300	Military motor vehicle assembly	Industrial Vehicles
37110301	Amphibian motor vehicles, assembly of	Industrial Vehicles
37110302	Personnel carriers (motor vehicles), assembly of	Industrial Vehicles
37110401	Brooms, powered (motor vehicles), assembly of	Industrial Vehicles
37110403	Fire department vehicles (motor vehicles), assembly of	Industrial Vehicles
37110404	Mobile lounges (motor vehicle), assembly of	Industrial Vehicles
37110407	Road oilers (motor vehicles), assembly of	Industrial Vehicles
37110408	Snow plows (motor vehicles), assembly of	Industrial Vehicles
37110410	Street sprinklers and sweepers (motor vehicles), assembly of	Industrial Vehicles
37110411	Wreckers (tow truck), assembly of	Industrial Vehicles
37510100	Motorcycles and related parts	Motorcycles
37510102	Motor scooters and parts	Motorcycles
37110406	Motor homes, self contained, assembly of	Recreational Vehicles
37160000	Motor homes	Recreational Vehicles
37169900	Motor homes, nec	Recreational Vehicles
37169901	Recreational van conversion (self-propelled), factory basis	Recreational Vehicles
37990300	Off-road automobiles, except recreational vehicles	Recreational Vehicles
37990303	Midget autos, power driven	Recreational Vehicles
37110101	Ambulances (motor vehicles), assembly of	Trucks
37110103	Cars, armored, assembly of	Trucks
37110200	Truck and tractor truck assembly	Trucks
37110201	Motor trucks, except off-highway, assembly of	Trucks
37110202	Truck tractors for highway use, assembly of	Trucks
37110203	Trucks, pickup, assembly of	Trucks

Understanding the automotive manufacturing labor market

To understand the auto manufacturing labor market, Brookings used multiple datasets and created a variety of measures to examine the supply and demand of workers in auto-related occupations.

Identifying auto-specialized occupations and their educational profiles

A central tension in labor market analysis is whether to analyze industries or occupations. Industry refers to the kind of business carried out by a person's employing organization (e.g. the kind of good or service that firm produces). Occupation describes the kind of work a person does on the job. For workforce analysis and planning purposes, information on occupation by industry is ideal, yet that information is only available nationally and not at the state level.

In order to narrow the analysis to the most relevant occupations, Brookings identified occupations with high occupational specialization in the auto industry. The auto industry is defined as establishments in following four-digit North American Industry Classification System (NAICS) codes: 3361 (motor vehicle manufacturing), 3362 (motor vehicle body and trailer manufacturing), and 3363 (motor vehicle parts manufacturing). The Bureau of Labor Statistics industry-occupation matrix, which apportions occupations to industries at the national level, was used to identify occupations within those three NAICS codes. Brookings then calculated automotive occupational specializations to determine which occupations, as defined by six-digit Standard Occupational Classification (SOC) codes, are disproportionately represented in the auto industry, using the following calculation:

$$\frac{\text{(Employment for given occupation in NAICS 3361+3362+3363 / Total employment for NAICS 3361+3362+3363)}}{\text{(Employment for given occupation in all industries / Total employment for all industries)}}$$

Sixty occupations had a score above 1, indicating that they have high occupational specializations in the auto industry. These occupations formed the backbone of the analysis. For ease of presentation and analysis, these 60 occupations were aggregated into three clusters: production and maintenance; engineering and design; and managerial, business, and operations. (Please see Appendix D for the complete list of the occupations by cluster.)

To develop profiles for each occupation based on its typical education and training requirements, the Brookings team drew from two U.S. Department of Labor sources:

- *O*NET (Occupational Information Network),* a database developed by the Employment and Training Administration that provides a wealth of information on more than 1,000 occupations. O*NET educational data are based on surveys of incumbent workers and occupational experts who describe the level of education required if someone were to be hired for a particular occupation. Educational levels are: less than a high school diploma; high school diploma; postsecondary certificate; some college courses; associate's degree; bachelor's degree; post-baccalaureate certificate; master's degree; post-master's certificate; first professional degree; doctoral degree; and postdoctoral training.

- *The education and training classification system developed by the Bureau of Labor Statistics.* BLS economists use a mixture of qualitative and quantitative information to determine the typical education level needed to enter an occupation. Categories are similar but not identical to the O*NET categories and are as follows: less than high school; high school diploma or equivalent; some college, no degree; postsecondary non-degree award; associate's degree; bachelor's degree; master's degree; doctoral or professional degree. The Brookings team also compiled BLS information on typical on-the-job training needed to attain competency in an occupation. Categories included internship/residency; apprenticeship; long-term on-the-job training (more than one year); moderate-term on-the-job training (1-12 months); short-term on-the-job training (one month or less); and none.

When the O*NET and BLS datasets provided different information on the typical educational level required to enter an occupation, the higher level of educational attainment was used.

Establishing the current labor supply for the Tennessee auto industry

Using the BLS Occupational Employment Statistics (OES) dataset, Brookings identified the number of workers and average annual wages for each auto-specialized occupation in Tennessee between 2006 and 2012. Although workers in these occupations are employed across multiple industries, they are disproportionately found in the auto industry. Workers in auto-specialized occupations represent the current labor pool that is most likely to possess the necessary skills for jobs at auto OEMs and suppliers, and from which OEMs and suppliers can draw to fill their openings.

Since retirements can create new job openings for other workers, Brookings created estimates of worker age by occupation using the 2011 Integrated Public Use Microdata Series (IPUMS). Based on the small sample size for Tennessee, the Census-designated Southern region of the United States was used.

Estimating labor demand for auto-specialized occupations

The Conference Board's Help Wanted Online data series
The primary measure to assess labor market demand was data on job openings from the Conference Board's Help Wanted Online (HWOL) data series. These data represent all online advertised job vacancies, which are accumulated from a large number of online job boards before removing duplicate announcements. Data used in this report cover the period 2006–2012 and include all six-digit SOC occupations. Data for the time period 2006–2011 include job openings in Tennessee's four largest metropolitan areas (Knoxville, Nashville, Chattanooga, and Memphis), while data for 2012 include job openings statewide and at the metropolitan level, including counties in adjacent states that are part of Tennessee-based metropolitan areas.

HWOL provides data on the following variables:

- Total ads: unduplicated job advertisements appearing in the reference period (a one-month period)
- New ads: unduplicated job advertisements that did not appear in the previous reference period

From these variables, Brookings created a "hard-to-fill" measure, defined as those with job advertisements posted longer than one month.

The fact that the HWOL dataset is based on advertised online vacancies raises questions as to whether or not certain kinds of jobs are more or less likely to be advertised online. A comparison of online job postings from the HWOL series to employment counts from the BLS Occupational Employment Survey at the two-digit SOC code for the state of Tennessee found that professional occupations were overrepresented and production occupations were underrepresented in HWOL compared to the Tennessee employment base. Anecdotal information indicates that manufacturers use different recruiting methods for different occupational groups, with production workers more likely to be hired by word-of-mouth, signs, and referrals than professional workers. Thus, it is likely that the HWOL-based measures underrepresent demand for production workers and, given this sampling bias, measures of "hardness-to-fill" between occupational clusters are not perfectly comparable.

Unemployment rates
Estimates of unemployment rates by occupation are from the 2011 Integrated Public Use Microdata Series and are for the Southern region of the United States, using the Census Bureau's regional definition. Occupational estimates were aggregated to develop unemployment rates for the three occupational clusters. High unemployment in a given occupation suggests ample supply of potential workers, while low unemployment suggests stronger demand and a potential shortage.

Estimating the size of the workforce pipeline by identifying Tennessee postsecondary education and training programs that lead into auto-specialized occupations

The Brookings team used O*NET's CIP-SOC crosswalk to identify postsecondary certificate, diploma, and degree programs that are associated with auto-specialized occupations. (CIP stands for Classification of Instructional Programs, a national taxonomy of educational programs by fields of study.) For example, the following educational programs can lead to a job as

a mechanical engineer: CIP 15.0612 (industrial technician), CIP 15.1501 (engineering/industrial management), CIP 15.0699 (industrial production technician), CIP 15.0613 (manufacturing engineering technician.).

Because one CIP code can lead to many SOC codes and one SOC code can draw from many CIP codes, the pool of eligible graduates for an occupation overlaps with other occupations that share fields of study. For this reason occupations with broad instructional requirements will have significantly higher quantities of eligible graduates.

Once the research team identified the relevant fields of study by CIP code, the National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS) Completions Survey was used to identify the number of certificates, degrees, and diplomas conferred by Tennessee postsecondary institutions in those fields of study that pertain to a particular occupation using the O*NET CIP-SOC crosswalk.

APPENDIX B. COMPANIES IN BROOKINGS' D&B ESTABLISHMENT DATABASE

AR Express
AAA Coatings, Inc.
ABC Group Fuel Systems, Inc.
ABC INOAC Exterior Systems, LLC
ABC Technologies, Inc.
ABMA, LLC
AC Valve Control Co.
Accessible Systems, Inc.
Accuride Corporation
Active Burgess Tennessee, Inc.
Acument Global Technologies, Inc.
Advanced Labelworx, Inc.
Advanced Tooling Solutions, Inc.
Advantage Freight Transfer, Inc.
Adventure Sports
AFG Industries, Inc.
Aggressive ATV
Agility Fuel Systems, Inc.
Airgroup
Aisin Automotive Casting Tennessee, Inc.
Albright Trailer Manufacturing, LLC
Alco Valves, Inc.
Alemite, LLC
Alexander Inventions
Allison Corporation
Alpha Integration, Inc.
American Brake Systems, Inc.
American Fabricators, Inc.
Angus Industries, Inc.
ANSEI America, Inc.
Apex Trailer Leasing & Rental
Arbon Equipment Corporation
ARC Automotive, Inc.
ARJ Manufacturing, LLC
Arvin Sango, Inc.
Assurance Operations Corporation
Atwood Mobile Products, LLC
Automotive Accents, LLC
Axletek Engineered Products, Inc.
B&B Manufacturing, LLC
Barnett Enterprises, Inc.
BASF Corporation
Bates Acquisition, LLC
Battle Creek Supercross, Inc.
Baxter Enterprises, LLC
BBB Industries, LLC
Bellex, Inc.
Bennett Tool & Die Co., Inc.
Benton Plastics, Inc.
BH Electronics, Inc.
Blackline, LLC
BNA Global
Bodine Aluminum, Inc.
Bohannon Concepts
Borla Performance Industries, Inc.
Boss Hoss Cycles, Inc.
BPSC Solutions
Bridgestone Americas Tire Operations, LLC
Bridgestone Americas, Inc.
Bridgestone APM Company
Bridgestone Industrial Products America, Inc.
Briggs & Stratton Corporation
Brunswick Corporation
Bushtec Manufacturing & Sales, Inc.
Calsonic Kansei North America, Inc.
Cannon's Racks & Axles
Cargo Carrier Corporation
Carlex Glass America, Inc.
Carlisle Tire & Wheel Company
Century Holdings, Inc.
Century Mold Company, Inc.
Champion Carrier Corporation
Chassis Craft
Chattanooga Seating Systems, LLC
Cherokee Truck Equipment, LLC
Chroma Graphics, Inc.
Clarcor, Inc.
Clarion Corporation of America
Clinton Cycle Works
Coleman-Taylor Automatic Transmission Co., Inc.
Collins & Aikman Carpet & Acoustics, Inc.
Colonial Diversified Polymer Products, LLC
Comco USA, Inc.
Command Automotive, Inc.
Commercial Truck & Equipment, Inc.
Competition Cams, Inc.
Consolidated Metco, Inc.
Contech Castings, LLC
Convoy Solutions, LLC
Cooper-Standard Automotive, Inc.
Coors Technical Ceramics Company
Cottrell Truck & Equipment
Crane Interiors, Inc.
Cummins Filtration, Inc.
Cummins, Inc.
Cupples' J & J Co., Inc.

Custom Metal Products
Custom Springs, Inc.
Cvg Cs, LLC
Cycle Gear, Inc.
Cytec Industries, Inc.
D & C Construction
D DMT Enterprises
DACCO, Inc.
Daiei America, Inc.
Dana Commercial Vehicle Products, LLC
Dana Driveshaft Products, LLC
Dana Holding Corporation
Dana Sealing Products, LLC
Daniel's Automotive & Machine Service
Daycab Company, Inc.
DB Electrical, Inc.
Decostar Industries, Inc.
Deka Battery & Accessories
DENSO Manufacturing Tennessee, Inc.
DIEnamic Tool & Die, Inc.
Diesel Head & Parts Service, Inc.
Diesel Performance Parts, Inc.
Dills Development Corporation
Diversatech Plastics Group, LLC
DLH Industries, Inc.
Donaldson Company, Inc.
Donnell, Inc.
Doodleco, Inc.
Dorman Products, Inc.
DSS Prodiesel Partners, LLC
Dual-Tech, Inc.
Dura Automotive Systems, LLC
Dura Operating, LLC
E Double Co.
EV Charge America
E&E Manufacturing of Tennessee, LLC
Eagle Bend Manufacturing, Inc.
Eagle Valve Solutions, Inc.
Eagle Wire Products
East Penn Manufacturing Co., Inc.
Eastern Plating, Inc.
Eaton Corporation
Emerson Electric Company
End of the Road, Inc.
Epic Technologies, LLC
Essex Group, Inc.
Excel Polymers, LLC
Exedy America Corporation
Exide Technologies, Inc.
FEE, Inc.
Fabricating Services, Inc.
Faltec America, Inc.
Fas Break
Faurecia Emissions Control Technologies USA, LLC
Federal-Mogul Corporation
Federal-Mogul FAP, Inc.
Ficosa North America Corporation
Filter Specialists, Inc.
Fine Tool Plastic/Metal Components, Inc.
Firestone Industrial Products Company, LLC
Fleetheet, LLC
Flex Technologies, Inc.
Flexible Whips of Tennessee, Inc.
Flint Hydrostatics, Inc.
Fluid Equipment Corporation
Fluid Routing Solutions, Inc.
Fluitek Corporation
Fontaine Spray Suppression Company
Fostoria Industries, Inc.
Four Lane, Inc.
Fowler's Transmissions
Fraley & Schilling, Inc.
Freightliner, LLC
Fuel Air Spark Technology
FXI, Inc.
GNU, Inc.
Garner Rebuilt Water Pumps, Inc.
Gastite Products, LLC
GCT Manufacturing, LLC
GENCO Stamping and Manufacturing Company
Gene A Fults & Son, Inc.
General Motors, LLC
Genesis One Stroke Engine Company
Gestamp Chattanooga, LLC
Gibson Motor Cars, LLC
Glorified Transport
Grass Choppers
Great Dane Ltd. Partnership
Greer Stop Nut, Inc.
Grooms Engines-Parts-Machining, Inc.
GSE
H & H Hydraulics, LLC
H & O Tool & Die, Inc.
H E R H D, Inc.
Harney's Carburetor Clinic, LLC
Havco Wood Products, LLC
HBD Industries, Inc.
Heartland Miniature Motor
Heckethorn Manufacturing Co., Inc.
Heil Trailer International, Co.
Helm Corporation
Hendrickson International Corporation
Hennessy Industries, Inc.
Henniges Automotive Technical Center, Inc.
Hi-Tech Mold & Engineering, Inc.
Holderfield Battery Company, Inc.
Holley Performance Products
Homesteader, Inc.
Hopkins Tooling, Inc.
Howard Baer, Inc.
Howmet Castings & Services, Inc.
Huf North America Automotive Parts Mfg. Co.
Hurst Trailers, Inc.
Hutchinson FTS, Inc.
Hutchinson Sealing Systems, Inc.
Hydratrek, Inc.
Hypertech, Inc.
IAC Springfield, LLC
Idea Bright Group, LLC
Ilene Industries, Inc.
Illinois Tool Works, Inc.
IMCO-Maremont Chicago, Inc.

Imperial Image, LLC
Indmar Products Co., Inc.
Industrial Converting Co., Inc.
Industrial Design & Fabrication, Inc.
Industrial Modeling International, LLC
Inland Manufacturing, Inc.
Innovative Research
Insight Associates
Insight Equity Acquisition Company, LLC
International Muffler Company
International Tooling and Stamping, Inc.
J.R. Manufacturing, Inc.
Jabil Circuit, Inc.
Jacobs Technology, Inc.
JM Enterprises, Inc.
John W McDougall Co., Inc.
Johnny's Floor Mats
Johnson Controls, Inc.
Jones Exhaust Systems, Inc.
Jones Plastic and Engineering Company, LLC
JOST International Corporation
JTEKT Automotive Tennessee, Inc.
K & S Fiberglass Corp
K & V Automotive, Inc.
K Bay Auto Parts, LLC
KSE Racing Products, Inc.
K-1 Auto Glass, Inc.
Kaiser Aluminum Corporation
Kantus Corporation
Kawasaki Tennessee, Inc.
Ken Tenn Truck & Trailer
Kennametal, Inc.
Kennedy & Bowden Machine Co., Inc.
Kentucky Flatbeds
Key Safety Restraint Systems, Inc.
Kongsberg Automotive, Inc.
Koyo Corporation of U.S.A.
Koyo Delaware, Inc.
L & L Alternator Rebuilders
L & T Services, LLC
Lab Industries, Inc.
Lam International Corp., USA
Le Carra, Inc.
Lear Corporation
Leggett & Platt, Inc.
Leonard Aluminum Utility Buildings, Inc.
Lokar, Inc.
MIS, Inc.
Macdowall Enterprises, Inc.
Mag USA, Inc.
Magna Seating of America, Inc.
Magneti Marelli North America, Inc.
Magnum Manufacturing, Inc.
MAHLE Filter Systems North America, Inc.
MAHLE Industries, Inc.
Major's Master Muffler
Mann + Hummel USA, Inc.
Manufacturers Industrial Group, LLC
Maremont Exhaust Products, Inc.
Martinrea Automotive Systems, LLC
Martinrea Fabco Automotive Structures, Inc.
Mason Machinings, Inc.
Master Auto Parts
Matix Corporation
Matsuo Industries USA, Inc.
Matthey Johnson, Inc.
Maxera LLC
Maxx Automotive Corporation
MCBC Holdings, Inc.
MDW, Inc.
Mechanical Components of Tennessee, Inc.
Mechanical Innovations, Inc.
Memphis Shades, Inc.
Memphis X Coat, Inc.
Meritor, Inc.
Metal Fabrication, Inc.
Met-L Tek, Inc.
Metokote Corporation
Metrican Stamping, LLC
MGM Brakes
Micro Metals, Inc.
Microporous Products, LP
Mid Tenn Automation
Mid-South Wire Company, Inc.
MIG Wire and Tube, LLC
MIG-Visteon Automotive Systems, LLC
Miller Industries, Inc.
Minnewawa, Inc.
Mississippi Coastal Carriers
Mitsuchi Corporation of America
Modine Manufacturing Company
Moeller Manufacturing Company, Inc.
Molded Metal Services, Inc.
Monroe Motors, Inc.
Moore Equipment Co.
Morrill Motors, Inc.
Morrison Tool & Fab, Inc.
Motor Wheel Commercial Vehicle Systems, Inc.
Motorcar Parts of America, Inc.
MRC Industries, LLC
MTD Products, Inc.
M-Tek, Inc.
Mueller Fittings Company, Inc.
Mueller Industries, Inc.
Mueller Refrigeration Company, Inc.
N A Williams Co., Inc.
N K Truck & Trailer Supply
N. N. Ball & Roller, Inc.
NACCO Materials Handling Group, Inc.
Nakatetsu Machining Technologies, LLC
NASG Tennessee North, LLC
Nash Build Custom Assembly, Inc.
Nashville Coach Works, Inc.
National Industrial Concepts, Inc.
Navex, Inc.
Navistar International Corporation
Neal Induction System
Nemak USA, Inc.
NESCO, Inc.
New Deal Tool and Die Co.
NHK Seating of America, Inc.
Nissan North America, Inc.

Nissan Trading Corporation Americas
NN, Inc.
Nogas, LLC
Noranda Aluminum Acquisition Corporation
Noranda Intermediate Holding Corporation
Novita Technologies, Inc.
Nuera Transport, Inc.
Numatics, Inc.
NYX, Inc.
OB Lane Company
OEM Cycle
O-Flex Automotive, Inc.
O-Flex Tube, Inc.
Ooltewah Manufacturing, Inc.
Oozx USA.Inc.
Optimum Polymer Technologies, Inc.
Orchid Automation Systems, Inc.
Orchid Mt. Juliet, LLC
OTICS USA, Inc.
Overstreet-Hughes Co., Inc.
Page Industries
Parker-Hannifin Corporation
PBR Knoxville, LLC
Perfect Equipment, Inc.
Perfections Worx
Petoskey Plastics, Inc.
Phoenix USA, Inc.
Pioneer Manufacturing, Inc.
PML, Inc.
Polymer Industrial Products Co., LLC
Powder Cote II, LLC
Pretoria Transit Interiors, Inc.
Pro Tech Industries, Inc.
Procix, LLC
Production Plus Precision Machining, LLC
Profile Metal Forming, Inc.
Protomet Corporation
Purodenso Co.
Purolator Products N A, Inc.
Quality Industries, Inc.
Quaprotek USA LP
RADOC Corporation
Rebel North America, LLC
Recon Distribution Center
RediAir
Reflexxion Automotive Products, LLC
Remosa Valves Company
Remotec, Inc.
Resource Recovery Systems, Inc.
Revel Enterprises, Inc.
Rexnord Industries, LLC
Rhino Linings, Inc.
Rhoades National Corporation
Richland, LLC
Ride Control, LLC
Ridgeline, Inc.
Ripley Industries, Inc.
Robert Bosch, LLC
Roberts Brothers Coach Co., Inc.
Rockford Cooper-Standard, Inc.
Rogers Manufacturing Co., Inc.
Rotenberry Motorsports, LLC
ROX Performance, LLC
S & S Powersports, LLC
S&S Screw Machine Company, LLC
S/G Industries, Inc.
Saargummi Tennessee, Inc.
Safety Werks, LLC
SAIA-Burgess Automotive Actuators, Inc.
Salga Plastics Inc.
San-Ei Seiko America, Inc.
Savannah Machine Shop & Loader Company
Scan Air Filter Corporation
Schmiede Corporation
Schrader Electronics, Inc.
Select Arc, Inc.
Select-Tech, Inc.
Setco Automotive North America, Inc.
SFI of Tennessee, LLC
Shiloh Industries, Inc.
Shoals Technologies Group, Inc.
Siegel-Robert, Inc.
Signal Specialty Company
Silver Eagle Bus Manufacturing, Inc.
Siskin Steel & Supply Company, Inc.
Sivad, Inc.
SL America Corporation
SL Tennessee, LLC
SMW Automotive Corporation
Snap-On, Inc.
Solideal USA
Southeast Color, Inc.
Southeastern Brake & Clutch, Inc.
Southern Auto Electric
Southtec, LLC
Specialty Autoworks, Inc.
Speedsource, Inc.
Sportsdrive, LLC
Spurlock Vehicles, Inc.
Stallion Engine Company, Inc.
Stoneridge, Inc.
Storie Manifolds
Sturdy-Lite, Inc.
Sumitomo Electric Wiring Systems, Inc.
Super Grip Corporation
Superior Coach Interiors, Inc.
Superior Industries International, Inc.
Superior Mobile Windshield
Superior Unlimited Corporation
Surwic Trailer Hitch Co., Inc.
SW & Sons USA, Inc.
SW Manufacturing, Inc.
Sweetwater Metal Products, Inc.
T & C Corp.
TNT Enterprises
Taiho Manufacturing of Tennessee
Takahata Precision America, Inc.
Tarasport Trailers, Inc.
TDY Industries, LLC
Technology Network for Safe Roads
Tecumseh Products Company
TEFCO, Inc.

Teksid Aluminum Foundry, Inc.
Tel-Trax Co.
Tenex, Inc.
Tenn Trans Tech
Tenneco, Inc.
Tennessee DTR., Inc.
Tennessee HUF
Tennessee Koide, Inc.
Tennessee NASG South, LLC
Tennessee Nichirin, Inc.
Tennessee TBDN Company.
Tennessee Tool & Engineering, Inc.
Tennessee Trailers, Inc.
Tennessee Wheel & Rubber Company, Inc.
Tennessee Wire Technologies, LLC
Tennessee Zanini, Inc.
Tepro, Inc.
Terex Corporation
Tesma International, Inc.
The Bailey Company, Inc.
The Crown Group, Inc.
The Heil Company
The Moto Show Parts Company
The Troxel Company
The Wise Co, Inc.
Thermal Solutions Manufacturing, Inc.
THK Rhythm North America Co., Ltd.
Thunder Heart Performance Corp.
Thunder Valley Cycle Co.
ThyssenKrupp Automotive Systems of America
TI Group Automotive Systems, LLC
Titan Tire Corporation
Toho Tenax America, Inc.
Townsend Engineered Product
Top Five, Inc.
Tool Products, LLC
Tottser-Iroquois Industries, LLC
Tower Automotive Operations USA, LLC
Toyo Seat USA
Toyota Motor Manufacturing
TPR Federal Mogul Tennessee
Trackpoint Systems, LLC
Trailer Billy
Trailer Specialists of Knoxville, Inc.
Trailmanor, Inc.
Travis Cagle, Inc.
Trew Industrial Wheels, Inc.
Trim Tek Manufacturing, Inc.
Triple T Coach, Inc.
Tri-Shell Enterprises, LLC
Truform Manufacturing, Inc.
TRW Automotive U.S., LLC
TRW Fuji Valve Inc.
TTE Casting Technologies, Inc.
Tuftora Automotive Carpet, Inc.
Turbo Auto-East
Turner Machine Co., Inc.
TWZ, Inc.
U.S. Farathane Corporation
U.S. Tsubaki Automotive, LLC
Underwood Enterprises, Inc.
Unipres U.S.A., Inc.
Unique Functional Products
Unlimited Manufacturing Industries, LLC
V Craig Enterprises
Valeo, Inc.
Van Rob Waverly, Inc.
Viam Manufacturing, Inc.
Vintec Co
Vista-Pro Automotive, LLC
Visteon Remanufacturing, Inc.
Volkswagen Group of America, Inc.
Volunteer Volvo and GMC, Inc.
Volvo Penta Marine Products, LLC
VR Volunteer, Inc.
Walker Die Casting, Inc.
Walker Radiator Works, Inc.
Warren Associates LLC
Waupaca Foundry, Inc.
Whirly Jig
Wilcas Wire Company
Wiles Welding & Machine Shop
Wil-Ro, Inc.
Windsor Mold USA, Inc.
Winn Performance
Wisconsin Motors, LLC
Wise Industries, Inc.
Woodbridge Foam Fabricating, Inc.
World Wide Automotive, LLC
World Wide Straight Drive
Wright Industries
WWL Vehicle Services Americas, Inc.
XS Power
Yazaki North America, Inc.
Yorozu America Corp.
Yorozu Automotive Tennessee, Inc.
Zeno's & Tight Whips Corp.

Appendix C SWOT Benchmark Table

Metric		Tennessee	Alabama	Georgia	Illinois	Indiana	Kentucky	Michigan	Mississippi	North Carolina	Ohio	South Carolina	Texas
General Economic Performance													
Overall Size and Growth	Output per Capita, 2012	$42,910	$38,064	$43,707	$53,998	$45,680	$39,600	$40,523	$34,001	$46,757	$44,125	$37,305	$53,623
	Total Output, 2012 (2005 chained, in billions)	$241	$157	$374	$594	$255	$147	$349	$86	$393	$435	$151	$1,212
	Annual Output Growth, 2010-2012 (2005 chained)	2.9%	1.1%	2.1%	2.0%	2.7%	1.7%	2.8%	0.6%	1.6%	2.5%	2.5%	4.2%
	Total Employment, 2012 (in thousands)	2,825	1,976	4,120	5,873	2,988	1,985	4,138	1,181	4,213	5,293	1,953	11,388
	Annual Employment Growth, 2010-2012	1.8%	0.4%	1.1%	1.1%	1.7%	1.6%	2.2%	0.3%	1.5%	1.4%	1.3%	2.5%
Advanced Industries	Annual Output Growth, 2010-2012 (2005 chained)	11.0%	6.2%	11.0%	7.1%	7.2%	10.9%	14.9%	13.2%	7.2%	11.0%	12.8%	9.8%
	Share of State Output, 2012	7.7%	6.4%	7.4%	7.9%	11.3%	6.1%	9.9%	3.6%	11.8%	6.8%	6.4%	7.7%
	Annual Employment Growth, 2010-2012	9.1%	4.6%	8.3%	6.6%	7.3%	12.2%	15.5%	13.9%	9.2%	8.7%	12.3%	9.5%
	Share of State Employment, 2012	4.5%	5.1%	4.6%	5.3%	6.4%	5.0%	7.4%	2.5%	5.5%	5.3%	4.3%	4.6%
Mfg. Sector	Annual Output Growth, 2010-2012 (2005 chained)	6.8%	7.0%	5.4%	7.2%	5.2%	5.8%	9.6%	-0.4%	1.8%	7.8%	7.5%	7.4%
	Share of State Output, 2012	14.9%	16.3%	11.2%	13.3%	28.2%	17.1%	16.5%	15.0%	19.4%	17.1%	16.3%	15.1%
	Annual Employment Growth, 2010-2012	2.4%	1.4%	1.4%	1.9%	3.9%	3.4%	6.5%	0.3%	0.9%	2.8%	3.0%	3.1%
	Share of State Employment, 2012	11.1%	12.3%	8.6%	9.9%	16.1%	11.3%	13.0%	11.6%	10.4%	12.4%	11.3%	7.6%
Labor Market	Compensation per Worker, 2012	$42,880	$40,928	$47,168	$53,389	$41,915	$38,965	$45,707	$36,697	$44,333	$44,886	$40,313	$49,557
	Motor Vehicle Industry Compensation per Worker, 2012	$57,226	$56,384	$53,886	$58,165	$58,982	$56,773	$77,831	$54,764	$58,485	$63,572	$61,396	$60,252
	Annual Growth in Worker Compensation, 2010-2012 (CPI-adjusted)	-0.2%	-0.8%	-0.3%	0.0%	0.1%	-0.6%	-0.3%	-0.4%	-0.4%	0.1%	-0.4%	0.7%
	Unemployment Rate, Seasonally Adjusted, June 2013	8.5%	6.5%	8.6%	9.2%	8.4%	8.4%	8.7%	9.0%	8.8%	7.2%	8.1%	6.5%
Trade	Share of Employment in Majority-Owned Foreign Affiliates, 2010	3.2%	3.3%	3.5%	3.4%	3.8%	3.8%	2.8%	1.7%	3.6%	3.2%	4.3%	3.0%
	Real Exports, 2012 (in billions)	$41.4	$29.7	$51.1	$93.4	$74.5	$30.3	$78.4	$15.2	$74.9	$80.8	$29.0	$216.7
	Annual Real Export Growth, 2003-2012	4.7%	6.0%	4.4%	5.6%	6.3%	5.1%	3.8%	5.6%	5.7%	3.7%	2.9%	8.7%
	Export Share of Output, 2012	14.9%	16.5%	11.6%	13.5%	25.8%	17.7%	19.7%	14.9%	16.3%	16.2%	16.8%	15.6%
	Export Freight per Worker in Transportation Equipment Sector, 2012	$12,791	$16,683	$11,836	$6,272	$15,030	$25,400	$33,150	$4,009	$4,480	$15,540	$21,143	$14,450
					***								
Competitiveness													
Business Climate	Beacon Hill Institute Infrastructure Index, 2011	5.2	4.9	5.2	5.1	4.8	5.0	4.9	4.6	5.2	5.1	4.7	5.2
	Initial Public Offerings Score, 2012	6.8	4.2	5.6	5.3	5.5	4.5	6.4	4.2	5.4	4.6	4.2	6.4
	Entrepreneurs per 100,000 People, 2011	290	260	350	200	200	370	220	260	280	270	290	440
	Share of Workforce Owning Microenterprises (0-4 employees), 2010	16.8	16.6	18.7	16	13.9	15.1	16.5	16.8	16.1	14.2	15.9	17.6
	Share of Workforce Owning Small Businesses (5-99 employees), 2010	1.24	1.36	1.22	1.33	1.36	1.31	1.36	1.33	1.32	1.31	1.36	1.23
State-Local Finances and Taxes	State Public Debt per Capita, 2010	922	1,841	1,426	4,790	3,650	3,323	3,251	2,182	1,983	2,703	3,419	1,679
	Overall State-Local Tax Burden Rate, 2010	7.7%	8.2%	9.0%	10.2%	9.6%	9.4%	9.8%	8.7%	9.9%	9.7%	8.4%	7.9%
	State Business Tax Climate Index Score, 2013	5.67	5.26	4.86	5.03	5.95	5.15	5.86	5.37	4.21	4.55	4.81	6.09
	Total Effective Tax Rate, New R&D Facilities, 2012	21.3%	16.9%	7.5%	16.9%	5.4%	9.6%	14.4%	12.6%	15.4%	9.9%	17.7%	21.3%
	Total Effective Tax Rate, New Labor-Intensive Manufacturing, 2012	13.7%	9.1%	7.1%	11.2%	11.0%	8.3%	6.4%	11.1%	7.5%	6.2%	7.9%	14.2%
	Unemployment Insurance Tax Score, 2013	4.9%	5.6%	4.9%	4.2%	5.7%	3.7%	4.1%	5.8%	6.0%	5.6%	4.7%	5.6%

State Rankings Key:	1-10	11-20	21-30	31-40	41-51

Appendix C SWOT Benchmark Table

Metric		Tennessee	Alabama	Georgia	Illinois	Indiana	Kentucky	Michigan	Mississippi	North Carolina	Ohio	South Carolina	Texas
Workforce													
Education Funding	Appropriations for Higher Education as Share of State Output, 2010	58.0%	84.0%	74.0%	47.0%	57.0%	74.0%	48.0%	103.0%	91.0%	41.0%	56.0%	54.0%
	Percentage of College Graduates with Student Loan Debt	53.0%	54.0%	58.0%	64.0%	63.0%	60.0%	62.0%	54.0%	54.0%	68.0%	54.0%	56.0%
	Total Expenditures per Pupil, 2009-2010	$9,007	$10,210	$10,704	$13,403	$10,845	$10,436	$12,002	$8,902	$8,965	$13,185	$11,360	$11,100
	Instruction Expenditures per Pupil, 2009-2010	$5,111	$5,211	$5,899	$7,027	$5,574	$5,314	$6,012	$4,765	$5,151	$6,417	$5,233	$5,309
General Education	State High School Graduation Rate, 2009-2010	89.0%	88.0%	81.0%	88.0%	84.0%	77.0%	76.0%	73.0%	74.0%	84.0%	72.0%	84.0%
	Share of 8th-Grade Students Proficient in Math, 2011	23.9%	20.1%	27.8%	32.8%	34.1%	30.7%	30.8%	19.3%	37.0%	38.9%	31.8%	40.0%
	Share of 8th-Grade Students Proficient in Reading, 2011	27.0%	25.6%	27.6%	33.9%	31.8%	36.3%	32.1%	21.0%	31.1%	36.9%	26.6%	26.5%
	Share of Adults with At Least 2-Year College Degree, 2011	29.6%	29.6%	34.2%	38.3%	30.9%	28.0%	34.1%	28.2%	35.6%	32.4%	32.6%	33.0%
	Share of Adults with At Least 4-Year College Degree, 2011	23.6%	22.3%	27.6%	31.0%	23.0%	21.1%	25.6%	19.8%	26.9%	24.7%	24.1%	26.4%
STEM in Higher Education	State STEM Awards as Share of Total Postsecondary Awards, 2011	18.0%	21.0%	24.8%	21.6%	22.1%	22.0%	21.9%	17.8%	23.0%	21.1%	21.6%	21.8%
	Change in State STEM Awards as Share of Total Postsecondary Awards, 2001-2011	-3.7%	-0.5%	-1.9%	-1.0%	-1.4%	0.0%	-1.4%	-3.0%	-1.9%	-1.8%	-2.8%	-4.8%
	Annual Growth in STEM Awards, 2001-2011	2.6%	3.2%	5.5%	3.6%	3.9%	7.3%	2.3%	1.9%	4.0%	2.9%	2.6%	3.3%
	STEM Awards as a Share of State Enrolled Population, 2011	3.2%	4.0%	4.8%	4.6%	4.3%	5.3%	3.5%	3.0%	4.0%	3.7%	3.5%	3.5%
STEM in Workforce	Share of State Jobs in STEM, 2011	5.4%	6.1%	5.7%	5.5%	5.4%	5.0%	7.3%	4.1%	6.2%	6.0%	5.6%	6.7%
	Change in Share of State Jobs in STEM, 2002-2011	33.1%	26.2%	15.0%	13.8%	23.7%	27.3%	17.9%	18.5%	25.0%	27.4%	33.1%	19.7%
	Share of STEM Jobs in Engineering, 2011	6.7%	8.2%	7.2%	7.4%	7.0%	5.5%	10.3%	5.0%	6.7%	7.7%	7.2%	9.2%
	Share of Bachelor's Degree Holders with STEM Degrees, 1-Year Estimate, 2011	29.4%	30.7%	28.7%	29.4%	31.6%	30.5%	33.2%	28.9%	29.7%	30.2%	28.3%	32.2%
	Share of Bachelor's Degree Holders with S&E Degrees, 3-Year Estimate, 2011	29.7%	31.3%	29.5%	30.1%	32.1%	30.3%	33.4%	29.7%	30.4%	30.7%	28.9%	33.0%
	Share of S&E Workers under Age 35, 2010	28.9%	30.4%	30.0%	33.0%	31.1%	34.7%	27.0%	33.4%	28.1%	31.7%	29.6%	32.4%
	Share of S&E Workers Age 55 and Over, 2010	20.8%	19.5%	13.6%	16.5%	17.5%	16.4%	16.6%	18.4%	15.6%	17.6%	19.1%	16.8%
	Net Intrastate Migration of Workers with a Bachelor's Degree, 2011	6,264	1,705	14,437	5,415	-171	3,885	-7,567	-1,100	21,122	912	9,064	65,636
	Immigration of Knowledge Workers Score, 2012	13.8	13.2	12.5	12.8	12.6	11.3	13.6	13.4	13.1	12.7	12.4	11.5
Innovation System													
R&D	Share of State Industry R&D Output, 2008	0.7%	1.8%	0.8%	1.4%	1.9%	0.6%	3.7%	0.3%	1.5%	1.6%	0.8%	1.4%
	Share of State Non-Industry R&D Output, 2008	0.9%	1.0%	0.5%	0.5%	0.4%	0.3%	0.5%	0.6%	0.6%	0.6%	0.5%	0.3%
Higher Ed. R&D Funding	Share of Federally Funded Higher Ed. R&D Expenditures for S&E, 2011	71.0%	64.3%	66.0%	66.3%	49.0%	50.1%	60.9%	61.1%	62.7%	65.9%	55.4%	51.0%
	Share of State/Local Govt. Financed Higher Ed. R&D Expenditures for S&E, 2011	3.5%	4.4%	2.7%	2.4%	5.0%	10.8%	2.5%	15.2%	6.0%	7.3%	0.9%	14.9%
	Share of Business Financed Higher Ed. R&D Expenditures for S&E, 2011	3.1%	3.6%	5.1%	4.3%	5.2%	3.7%	2.9%	4.1%	11.9%	7.0%	4.8%	6.2%
Federal Research Awards	NSF Awards per Million Residents, 2011	2.26	2.29	3.01	3.93	4.61	1.47	4.04	1.44	3.91	2.51	2.52	2.42
	Number of NSF Awards, 2012	144	110	293	506	300	64	400	43	374	290	117	611
	Share of all NSF Awards Received, 2012	1.3%	1.0%	2.6%	4.5%	2.7%	0.6%	3.5%	0.4%	3.3%	2.6%	1.0%	5.4%
	SBIR & STTR Awards per 1,000 Workers, 2011	$4,690	$9,179	$5,425	$5,581	$5,463	$8,509	$17,820	$1,808	$19,169	$12,250	$7,475	$6,072
Patents	Patents per 1,000 individuals in S&E Occupations, 2011	12.9	6.5	13.1	18.3	16.4	11	21.7	6.1	17	16.5	9.2	16.7
	Patents in Auto by 10,000 Employees, 2010	9.4	7.3	40	54	20	6.4	73	8.03	28	28	14	89
Venture Capital	VC Dollars per Capita, 2011	$16.1	$0.7	$35.0	$53.1	$27.3	$1.9	$8.3	$0.0	$33.7	$17.6	$4.7	$56.9
	VC Dollars per Capita, Average 2005-2011	$12.4	$4.3	$35.9	$33.3	$15.4	$5.9	$13.2	$0.8	$41.1	$13.4	$5.2	$48.8
	VC Deals per Million Residents, 2011	5.0	0.4	5.5	6.9	2.1	1.4	3.0	0.0	4.9	5.2	0.6	6.0
	VC Deals per Million Residents, Average 2005-2011	3.4	1.2	6.9	5.0	2.1	1.9	2.9	0.3	5.7	4.6	1.1	6.6
	VC Deals Per Million in Output, 2007-2011	0.2	0.1	0.9	0.6	0.4	0.1	0.5	0.0	1.0	0.4	0.1	0.8
	State Rankings Key:								1-10	11-20	21-30	31-40	41-51

General Economic Performance		
Overall Size and Growth	Output per Capita, 2012	Brookings analysis of data from Moody's Analytics and U.S. Census Bureau, 2013.
	Total Output, 2012 (2005 chained, in billions)	Brookings analysis of data from Moody's Analytics, 2013.
	Annual Output Growth, 2010-2012 (2005 chained)	Brookings analysis of data from Moody's Analytics, 2013.
	Total Employment, 2012 (in thousands)	Brookings analysis of data from Moody's Analytics, 2013.
	Annual Employment Growth, 2010-2012	Brookings analysis of data from Moody's Analytics, 2013.
Advanced Industries	Annual Output Growth, 2010-2012 (2005 chained)	Brookings analysis of data from Moody's Analytics, 2013.
	Share of State Output, 2012	Brookings analysis of data from Moody's Analytics, 2013.
	Annual Employment Growth, 2010-2012	Brookings analysis of data from Moody's Analytics, 2013.
	Share of State Employment, 2012	Brookings analysis of data from Moody's Analytics, 2013.
Mfg. Sector	Annual Output Growth, 2010-2012 (2005 chained)	Brookings analysis of data from Moody's Analytics, 2013.
	Share of State Output, 2012	Brookings analysis of data from Moody's Analytics, 2013.
	Annual Employment Growth, 2010-2012	Brookings analysis of data from Moody's Analytics, 2013.
	Share of State Employment, 2012	Brookings analysis of data from Moody's Analytics, 2013.
Labor Market	Compensation per Worker, 2012	Brookings analysis of data from Moody's Analytics, 2013.
	Motor Vehicle Industry Compensation per Worker, 2012	Brookings analysis of data from Moody's Analytics, 2013.
	Annual Growth in Worker Compensation, 2010-2012 (CPI-adjusted)	Brookings analysis of data from Moody's Analytics, 2013.
	Unemployment Rate, Seasonally Adjusted, June 2013	Bureau of Labor Statistics Local Area Unemployment, 2013.
Trade	Share of Employment in Majority-Owned Foreign Affiliates, 2010	Brookings analysis of BEA Financial and Operating Data for U.S. Affiliates of Foreign Multinational Companies , 2010.
	Real Exports, 2012 (in billions)	Brookings analysis of data from BEA, BLS, IRS, Moody's Analytics, NAFSA, and Census USA Trade Online.
	Annual Real Export Growth, 2003-2012	Brookings analysis of data from BEA, BLS, IRS, Moody's Analytics, NAFSA, and Census USA Trade Online.
	Export Share of Output, 2012	Brookings analysis of data from BEA, BLS, IRS, Moody's Analytics, NAFSA, and Census USA Trade Online.
	Export Freight per Worker in Transportation Equipment Sector, 2012	Brookings analysis of data from International Trade Administration, TradeStats Express, 2013.
	***	
Competitiveness		
Business Climate	Beacon Hill Institute Infrastructure Index, 2011	Beacon Hill Institute, "Eleventh Annual State Competitiveness Report," 2011.
	Initial Public Offerings Score, 2012	The Information Technology and Innovation Foundation, "The 2012 State New Economy Index," 2012.
	Entrepreneurs per 100,000 People, 2011	Brookings analysis of Kauffman Index of Entrepreneurial Activity, 2011.
	Share of Workforce Owning Microenterprises (0-4 employees), 2010	Corporation for Enterprise Development, "Assets and Opportunities Scorecard," 2010.
	Share of Workforce Owning Small Businesses (5-99 employees), 2010	Corporation for Enterprise Development, "Assets and Opportunities Scorecard," 2010.
State-Local Finances and Taxes	State Public Debt per Capita, 2010	Brookings analysis of data from Tax Foundation and U.S. Census Bureau, 2010.
	Overall State-Local Tax Burden Rate, 2010	Tax Foundation, "State and Local Tax Burdens: All States, One Year, 1977-2010," 2010.
	State Business Tax Climate Index Score, 2013	Tax Foundation, "State Business Tax Climate Index 2011-2012," 2012.
	Total Effective Tax Rate, New R&D Facilities, 2012	Tax Foundation and KPMG, "Location Matters: A Comparative Analysis of State Tax Costs on Business," 2012.
	Total Effective Tax Rate, New Labor-Intensive Manufacturing, 2012	Tax Foundation and KPMG, "Location Matters: A Comparative Analysis of State Tax Costs on Business," 2012.
	Unemployment Insurance Tax Score, 2013	Tax Foundation, "2013 State Business Tax Climate Index," 2013.

Workforce		
Education Funding	Appropriations for Higher Education as Share of State Output, 2010	National Science Foundation, "Science and Engineering Indicators 2012," Table 8-27, 2012.
	Percentage of College Graduates with Student Loan Debt	Corporation for Enterprise Development, "Assets and Opportunities Scorecard," 2010.
	Total Expenditures per Pupil, 2009-2010	Brookings analysis of National Center for Education Statistics, Common Core of Data, 2010.
	Instruction Expenditures per Pupil, 2009-2010	Brookings analysis of National Center for Education Statistics, Common Core of Data, 2010.
	General Education	State High School Graduation Rate, 2009-2010
General Education	Share of 8th-Grade Students Proficient in Math, 2011	Brookings analysis of National Center for Education Statistics, "National Assessment of Educational Progress," 2011.
	Share of 8th-Grade Students Proficient in Reading, 2011	Brookings analysis of National Center for Education Statistics, "National Assessment of Educational Progress," 2011.
	Share of Adults with At Least 2-Year College Degree, 2011	Corporation for Enterprise Development, "Assets and Opportunities Scorecard," 2010.
	Share of Adults with At Least 4-Year College Degree, 2011	Corporation for Enterprise Development, "Assets and Opportunities Scorecard," 2010.
STEM in Higher Education	State STEM Awards as Share of Total Postsecondary Awards, 2011	Brookings analysis of National Center for Education Statistics, IPEDS Completions Survey on Degrees, 2013.
	Change in State STEM Awards as Share of Total Postsecondary Awards, 2001-2011	Brookings analysis of National Center for Education Statistics, IPEDS Completions Survey on Degrees, 2013.
	Annual Growth in STEM Awards, 2001-2011	Brookings analysis of National Center for Education Statistics, IPEDS Completions Survey on Degrees, 2013.
	STEM Awards as a Share of State Enrolled Population, 2011	Brookings analysis of National Center for Education Statistics, IPEDS Completions Survey on Degrees, 2013.
STEM in Workforce	Share of State Jobs in STEM, 2011	Brookings analysis of BLS Occupational Employment and Wage State Cross-Industry Estimates, 2011.
	Change in Share of State Jobs in STEM, 2002-2011	Brookings analysis of BLS Occupational Employment and Wage State Cross-Industry Estimates, 2011.
	Share of STEM Jobs in Engineering, 2011	Brookings analysis of BLS Occupational Employment and Wage State Cross-Industry Estimates, 2011.
	Share of Bachelor's Degree Holders with STEM Degrees, 1-Year Estimate, 2011	Brookings analysis of U.S. Census Bureau ACS 1-Year Estimates, 2011.
	Share of Bachelor's Degree Holders with S&E Degrees, 3-Year Estimate, 2011	Brookings analysis of U.S. Census Bureau ACS 3-Year Estimates, 2011.
	Share of S&E Workers under Age 35, 2010	Brookings analysis of Population Reference Bureau, Trends in Science and Engineering Labor Force Project, 2012.
	Share of S&E Workers Age 55 and Over, 2010	Brookings analysis of Population Reference Bureau, Trends in Science and Engineering Labor Force Project, 2012.
	Net Intrastate Migration of Workers with a Bachelor's Degree, 2011	Brookings analysis of data from U.S. Census Bureau, 2009-2011 American Community Survey.
	Immigration of Knowledge Workers Score, 2012	The Information Technology and Innovation Foundation, "The 2012 State New Economy Index," 2012.
Innovation System		
R&D	Share of State Industry R&D Output, 2008	The Information Technology and Innovation Foundation, "The 2012 State New Economy Index," 2012.
	Share of State Non-Industry R&D Output, 2008	The Information Technology and Innovation Foundation, "The 2012 State New Economy Index," 2012.
Higher Ed. R&D Funding	Share of Federally Funded Higher Ed. R&D Expenditures for S&E, 2011	National Science Foundation, "Survey of R&D Expenditures at Universities and Colleges, Higher Education R&D Survey," 2012.
	Share of State/Local Govt. Financed Higher Ed. R&D Expenditures for S&E, 2011	National Science Foundation, "Survey of R&D Expenditures at Universities and Colleges, Higher Education R&D Survey," 2012.
	Share of Business Financed Higher Ed. R&D Expenditures for S&E, 2011	National Science Foundation, "Survey of R&D Expenditures at Universities and Colleges, Higher Education R&D Survey," 2012.
Federal Research Awards	NSF Awards per Million Residents, 2011	Brookings analysis of National Science Foundation, "Budget Internet Information System," 2012.
	Number of NSF Awards, 2012	Brookings analysis of National Science Foundation, "Budget Internet Information System," 2012.
	Share of all NSF Awards Received, 2012	Brookings analysis of National Science Foundation, "Budget Internet Information System," 2012.
	SBIR & STTR Awards per 1,000 Workers, 2011	Brookings analysis of data from Small Business Innovation Research (SBIR.gov), 2012 and Moody's Analytics, 2012.
Patents	Patents per 1,000 individuals in S&E Occupations, 2011	Brookings analysis of data from U.S. Patent and Trademark Office, 2011.
	Patents in Auto by 10,000 Employees, 2010	Institute for Strategy and Competitiveness, 2010.
Venture Capital	VC Dollars per Capita, 2011	Brookings analysis from PricewaterhouseCoopers Moneytree Survey Data, 2012 and Census Bureau Population Estimates, 2012.
	VC Dollars per Capita, Average 2005-2011	Brookings analysis from PricewaterhouseCoopers Moneytree Survey Data, 2012 and Census Bureau Population Estimates, 2012.
	VC Deals per Million Residents, 2011	Brookings analysis from PricewaterhouseCoopers Moneytree Survey Data, 2012 and Census Bureau Population Estimates, 2012.
	VC Deals per Million Residents, Average 2005-2011	Brookings analysis from PricewaterhouseCoopers Moneytree Survey Data, 2012 and Census Bureau Population Estimates, 2012.
	VC Deals Per Million in Output, 2007-2011	National Science Foundation, Science and Engineering Indicators, 2012.

Appendix C: Benchmarking Tennessee's Economy

Automotive Industry Jobs by State

	Total Auto Jobs	Auto-maker Jobs	Supplier Jobs	Other Auto-Related Jobs	Jobs in Foreign-Owned Establish-ments	Jobs in Small and Medium-Sized Establish-ments (< 500 workers)	Jobs in Large Establish-ments (500-1000 workers)	Jobs in Very Large Establish-ments (>1000 workers)
Alabama	56,053	13,693	36,622	5,738	30,238	27,516	7,409	21,128
Georgia	50,877	4,349	38,010	8,518	21,683	27,252	10,019	13,606
Illinois	122,549	13,097	96,121	13,331	41,607	57,839	22,245	42,465
Indiana	177,752	26,327	132,862	18,563	54,450	83,099	29,747	64,906
Kentucky	86,298	20,229	56,191	9,878	39,293	45,847	16,778	23,673
Michigan	55,6129	166,973	343,681	45,475	174,055	188,252	68,244	299,633
Mississippi	16,150	5,500	8,292	2,358	6,120	9,452	3,398	3,300
North Carolina	89,273	23,296	60,677	5,300	33,275	36,542	14,804	37,927
Ohio	228,484	53,524	155,753	19,207	75,325	98,907	47,697	81,880
South Carolina	65,002	8,930	50,688	5,384	37,698	29,682	7,783	27,537
Tennessee	93,895	12,149	73,399	8,347	42,884	49,699	20,647	23,549
Texas	85,477	7,934	65,414	12,129	19,093	49,264	5,400	30,813

Source: Brookings Automotive Industry Database

Automotive Industry Supplier Jobs by State

	Basic Inputs Jobs	Body & Interior Jobs	Chassis Jobs	Electronics Jobs	Powertrain Jobs	Parts & Components Jobs
Alabama	6,252	10,562*	6,043*	5,820	4,369	3,576
Georgia	9,035*	11,151*	6,198*	3,568	2,980	5,078
Illinois	29,630*	16,051*	5,296	16,254*	13,479*	15,411
Indiana	26,570	18,042*	16,491*	13,216	32,855*	25,688*
Kentucky	12,802	13,582*	7,847*	6,096	8,348	7,516
Michigan	76,015	73,595*	18,168	28,298	107,278	40,327*
Mississippi	698	1,111	823	1,678	2,347	1,635
North Carolina	24,881*	4,736	4,317	6,070	6,682*	13,991
Ohio	55,326*	26,328*	16,013*	10,863	24,531	22,692
South Carolina	11,499*	5,032	12,367*	2,918	12,286	6,586*
Tennessee	15,170	11,922*	7,985*	11,955*	16,313	10,054*
Texas	8,832	8,958	5,066	24,330*	12,130	6,098

Source: Brookings Automotive Industry Database
** denotes LQ > 1*

Appendix C: Benchmarking Tennessee's Economy

Automotive Industry Establishments by State

	Total Auto Establish-ments	Automaker Establish-ments	Supplier Establish-ments	Other Auto-Related Establish-ments	Foreign-Owned Establish-ments	Average Establishment Size (number of workers)	Median Establish-ment Size (number of workers)	Number of Small and Medium-Sized Establish-ments (< 500 workers)	Number of Large Establish-ments (500-1,000 workers)	Number of Very Large Establishments (> 1,000 workers)
Alabama	488	17	341	130	87	114.9	13.5	467	12	9
Georgia	721	8	517	196	88	70.6	6	698	15	8
Illinois	1130	35	823	272	122	108.5	13	1072	34	24
Indiana	1204	34	926	244	153	147.6	33.5	1125	45	34
Kentucky	558	20	387	151	147	154.7	48	523	26	9
Michigan	2861	222	2042	597	522	194.4	40	2621	107	133
Mississippi	194	8	132	54	15	83.2	13.5	188	5	1
North Carolina	789	20	562	207	93	113.1	8	750	22	17
Ohio	1631	55	1225	351	199	140.1	22	1520	70	41
South Carolina	439	10	337	92	97	148.1	19	414	13	12
Tennessee	643	30	490	123	109	146.0	40	598	31	14
Texas	1742	25	1243	474	92	49.1	4	1722	8	12

Source: Brookings Automotive Industry Database

Automotive Industry Supplier Establishments by State

	Basic Inputs Establishments	Body & Interior Establishments	Chassis Establishments	Electronics Establishments	Parts & Components Establishments	Powertrain Establishments
Alabama	45	82	55	37	67	55
Georgia	47	142	107	51	94	76
Illinois	168	144	97	110	185	119
Indiana	160	182	164	164	162	171
Kentucky	108	82	39	29	58	71
Michigan	401	473	147	188	306	527
Mississippi	10	27	29	14	21	31
North Carolina	71	123	101	46	139	82
Ohio	252	278	166	101	215	213
South Carolina	43	49	62	29	69	85
Tennessee	114	99	59	49	78	91
Texas	63	255	263	174	305	183

Source: Brookings Automotive Industry Database
** denotes LQ > 1*

APPENDIX D. AUTO-SPECIALIZED OCCUPATIONS

This appendix provides labor market information for the complete list of 60 auto-specialized occupations in Tennessee and the state's four largest metropolitan areas, organized into the three clusters of Production and Maintenance; Engineering and Design; and Managerial, Business, and Operations. Auto-specialized occupations are defined at the national level as those that represent a greater share of jobs in the motor vehicle industry than they do in the economy at large. The metric is conceptually akin to a location quotient and shows that these occupations are relatively—but not exclusively—concentrated in the automotive industry.

To assess labor market demand by occupation, the tables list information about each occupation, including unemployment rates, growth trajectories, number of hard-to-fill job postings (defined as those postings reposted more than once), total job postings, and hard-to-fill postings as a percent of total employment in the occupation. For more information on methods and definitions, see the labor market discussion in Appendix A. Values reported here should be considered approximate.

List of all 60 auto-specialized occupations

Occupations	Mean Wage, 2012	Occ. Emp., 2012	Annual Growth 2006-2012
Production & Maintenance	$41,650	110,370	-3.9%
*CNC Machine Tool Programmers	$40,980	470	-11.7%
Computer-Cntrld. Machine Tool Operators	$32,430	2,550	-6.1%
Cutting, Punching, & Press Workers	$31,340	6,630	-6.8%
Drilling & Boring Machine Tool Workers	$30,210	500	-15.6%
Electric Motor, Power Tool Repairers	$35,110	520	-0.3%
Electrical Installers/Repairers, Transport.	$43,330	410	-6.9%
Electricians	$42,860	11,110	-1.3%
Electronic Equipment Repairers, Vehicles	$30,510	160	-11.4%
Engine & Other Machine Assemblers	$30,970	1,520	-0.7%
Extruding & Drawing Machine Workers	$44,820	2,380	-3.1%
First-Line Sprvsrs., Mechanics & Installers	$57,290	8,590	-2.9%
First-Line Supervisors, Production Workers	$53,750	15,110	-3.5%
Forging Machine Workers	$32,960	610	-15.6%
Foundry Mold & Coremakers	$32,620	130	-2.4%
Grinding, Polishing, & Buffing Workers	$31,460	1,560	-7.4%
Heat Treating Equipment Workers	$34,190	450	-7.3%
Industrial Electrical Repairers	$47,830	1,390	-5.6%
Industrial Machinery Mechanics	$49,260	6,420	1.4%
Inspectors, Testers, Sorters, & Weighers	$34,160	11,200	-1.5%
Lathe & Turning Machine Tool Workers	$31,890	700	-19.8%
Layout Workers, Metal & Plastic	$32,120	200	4.9%
Machinists	$39,850	7,890	-6.0%
Maintenance Workers, Machinery	$40,340	2,720	-1.5%
Metal Workers & Plastic Workers, All Other	$32,820	160	-18.1%
Milling & Planing Machine Workers	$28,260	550	-3.5%
Millwrights	$40,960	900	-8.3%
*Model Makers, Metal & Plastic	$42,260	50	-16.7%
Multiple Machine Tool Workers	$31,250	2,580	7.2%
Painters, Transportation Equipment	$38,660	840	-13.9%
Plumbers, Pipefitters, & Steamfitters	$40,450	6,560	-3.0%
Precision Instrument Repairers, All Other	$54,480	480	17.8%
Rolling Machine Workers	$35,650	900	7.3%
Structural Metal Fabricators & Fitters	$34,800	1,930	-4.9%
Tool & Die Makers	$44,390	2,210	-3.6%
Tool Grinders, Filers, & Sharpeners	$35,470	120	-18.8%
Upholsterers	$23,800	870	-13.2%
Welders, Cutters, Solderers, & Brazers	$34,380	7,380	-3.8%
Welding, Soldering, & Brazing Workers	$30,550	1,620	-2.5%

Occupations	Mean Wage, 2012	Occ. Emp., 2012	Annual Growth 2006-2012
Engineering & Design	$73,246	21,660	3.1%
*Commercial & Industrial Designers	$59,650	400	-1.9%
Electrical & Electronics Drafters	$53,780	400	-8.7%
Electrical Engineers	$86,470	2,400	4.5%
*Electro-Mechanical Technicians	$57,820	240	0.0%
Engineering Technicians	$55,030	600	0.6%
Engineers, All Other	$84,350	2,770	2.5%
Health & Safety Engineers	$71,760	730	9.2%
Industrial Engineering Technicians	$52,300	1,570	3.9%
Industrial Engineers	$77,550	4,840	3.1%
*Materials Engineers	$81,200	270	-2.8%
Mechanical Drafters	$50,330	1,130	1.7%
Mechanical Engineering Technicians	$51,190	860	8.7%
Mechanical Engineers	$79,780	4,370	3.4%
Operations Research Analysts	$66,450	1,080	8.3%
Managerial, Business & Operations	$73,246	21,660	3.1%
Architectural & Eng. Managers	$105,000	2,460	-3.9%
Chief Executives	$153,720	10,520	-1.8%
Industrial Production Managers	$90,210	3,730	1.4%
Logisticians	$65,100	1,110	0.0%
Occ. Health & Safety Specialists	$62,670	1,420	12.0%
Prod., Planning, & Expediting Clerks	$41,550	7,010	1.8%
Purchasing Agents	$54,970	4,200	0.2%
Purchasing Managers	$81,150	1,830	-2.0%

**Denotes occupations designated as "hard-to-fill" at the state level but not meeting the minimum threshold for inclusion in the state table below due to small sample size*

Source: Brookings Analysis of BLS Occupation and Employment Statistics, 2012 and The Conference Board's Help Wanted Online, 2013. Statewide unemployment figures refer to the Census-defined Southern region of the United States.

Tennessee Statewide

Labor market information for auto-specialized occupations with 500 or more workers statewide

State Criteria: Shading indicates whether an occupation is designated as "hard-to-fill"							
(1) In order to be designated as a hard-to-fill occupation, hard-to-fill postings had to be greater than or equal to 10 percent of total employment in that occupation							
(2) Groups:	Hard-to-Fill Postings greater than or equal to 1000: Hardest-to-Fill						
	Hard-to-Fill Postings greater than or equal to 500 : Harder-to-Fill						
	Hard-to-Fill Postings greater than or equal to 100 and greater than 10% of 2012 occupation employment: Hard-to-Fill						
	Wages and Employment				**Demand**		
Occupation Title	**Mean Annual Wage, 2012**	**Occupation Emp., 2012**	**Annualized Growth 2006-2012**	**Regional Unemp. Rate, 2011**	**Hard-to-Fill Postings, 2012**	**Total Job Postings, 2012**	**Hard-to-Fill Postings/ Emp., 2012**
Production & Maintenance	**$41,650**	**110,370**	**-3.9%**	**9.9%**	**15,442**	**34,591**	**14.0%**
First-Line Supervisors, Production Workers	$53,750	15,110	-3.5%	6.1%	5,780	11,106	38.3%
First-Line Supervisors, Mechanics & Installers	$57,290	8,590	-2.9%	5.5%	2,954	6,281	34.4%
Industrial Machinery Mechanics	$49,260	6,420	1.4%	6.1%	1,089	2,329	17.0%
Machinists	$39,850	7,890	-6.0%	7.4%	1,016	2,207	12.9%
Welders, Cutters, Solderers, & Brazers	$34,380	7,380	-3.8%	10.2%	1,013	2,569	13.7%
Computer-Controlled Machine Tool Operators	$32,430	2,550	-6.1%	16.7%	542	1,164	21.3%
Tool & Die Makers	$44,390	2,210	-3.6%	10.7%	400	785	18.1%
Industrial Electrical Repairers	$47,830	1,390	-5.6%	2.4%	191	378	13.7%
Electricians	$42,860	11,110	-1.3%	12.7%	610	2,133	5.5%
Inspectors, Testers, Sorters, & Weighers	$34,160	11,200	-1.5%	10.9%	590	1,524	5.3%
Plumbers, Pipefitters, & Steamfitters	$40,450	6,560	-3.0%	14.3%	307	1,495	4.7%
Cutting, Punching, & Press Workers	$31,340	6,630	-6.8%	13.0%	264	657	4.0%
Extruding & Drawing Machine Workers	$44,820	2,380	-3.1%	6.4%	112	192	4.7%
Lathe & Turning Machine Tool Workers	$31,890	700	-19.8%	23.0%	69	176	9.9%
Upholsterers	$23,800	870	-13.2%	15.0%	47	162	5.4%
Millwrights	$40,960	900	-8.3%	10.7%	45	121	5.0%
Rolling Machine Workers	$35,650	900	7.3%	16.9%	37	104	4.1%
Welding, Soldering, & Brazing Workers	$30,550	1,620	-2.5%	12.5%	35	87	2.2%
Grinding, Polishing, & Buffing Workers	$31,460	1,560	-7.4%	12.2%	30	82	1.9%
Multiple Machine Tool Workers	$31,250	2,580	7.2%	10.2%	22	80	0.9%
Milling & Planing Machine Workers	$28,260	550	-3.5%	10.2%	21	31	3.8%
Painters, Transportation Equipment	$38,660	840	-13.9%	12.1%	16	186	1.9%
Structural Metal Fabricators & Fitters	$34,800	1,930	-4.9%	11.6%	14	117	0.7%
Drilling & Boring Machine Tool Workers	$30,210	500	-15.6%	20.4%	11	27	2.2%
Electric Motor, Power Tool Repairers	$35,110	520	-0.3%	7.5%	10	33	1.9%
Engine & Other Machine Assemblers	$30,970	1,520	-0.7%	15.8%	9	14	0.6%
Maintenance Workers, Machinery	$40,340	2,720	-1.5%	8.0%	6	18	0.2%
Engineering & Design	**$73,246**	**21,660**	**3.1%**	**4.3%**	**13,780**	**24,534**	**63.6%**
Industrial Engineers	$77,550	4,840	3.1%	2.9%	6,784	11,878	140.2%
Mechanical Engineers	$79,780	4,370	3.4%	3.9%	2,105	3,675	48.2%
Electrical Engineers	$86,470	2,400	4.5%	4.8%	1,854	3,076	77.3%
Operations Research Analysts	$66,450	1,080	8.3%	2.2%	663	1,170	61.4%
Industrial Engineering Technicians	$52,300	1,570	3.9%	7.7%	634	1,321	40.4%
Health & Safety Engineers	$71,760	730	9.2%	2.9%	620	1,140	84.9%
Engineers, All Other	$84,350	2,770	2.5%	1.0%	610	1,146	22.0%
Mechanical Drafters	$50,330	1,130	1.7%	9.8%	178	405	15.8%
Engineering Technicians	$55,030	600	0.6%	7.7%	51	120	8.5%
Mechanical Engineering Technicians	$51,190	860	8.7%	7.7%	36	75	4.2%
Managerial, Business, & Operations	**$94,294**	**32,280**	**-0.2%**	**0.0%**	**5,298**	**10,072**	**16.4%**
Purchasing Agents	$54,970	4,200	0.2%	5.3%	1,202	2,368	28.6%
Production, Planning, & Expediting Clerks	$41,550	7,010	1.8%	5.3%	849	1,703	12.1%
Architectural & Engineering Managers	$105,000	2,460	-3.9%	3.2%	773	1,329	31.4%
Purchasing Managers	$81,150	1,830	-2.0%	3.6%	713	1,347	39.0%
Logisticians	$65,100	1,110	0.0%	4.3%	605	1,057	54.5%
Industrial Production Managers	$90,210	3,730	1.4%	6.2%	601	1,192	16.1%
Occupational Health & Safety Specialists	$62,670	1,420	12.0%	8.0%	205	368	14.4%
Chief Executives	$153,720	10,520	-1.8%	2.7%	350	708	3.3%

Chattanooga, TN-GA Metropolitan Area

Labor market information for auto-specialized occupations designated as hard-to-fill or with at least 100 workers metro-wide

MSA Criteria: Shading indicates whether an occupation is designated as "hard-to-fill"							
(1) In order to be designated as a hard-to-fill occupation, hard-to-fill postings had to be greater than or equal to 10 percent of total employment in that occupation							
(2) Groups:	Hard-to-Fill Postings greater than or equal to 200 : Hardest-to-Fill						
	Hard-to-Fill Postings greater than or equal to 50 : Harder-to-Fill						
	Hard-to-Fill Postings less than 50 and greater than 10 percent of 2012 occupation employment: Hard-to-Fill						
	Wages and Employment				Demand		
Occupation Title	Mean Annual Wage, 2012	Occupation Emp., 2006	Occupation Emp., 2012	Annualized Growth 2006-2012	Hard-to-Fill Postings, 2012	Total Job Postings, 2012	Hard-to-Fill Postings/ Emp., 2012
Production & Maintenance	**$43,047**	**12,540**	**9,730**	**-4.1%**	**1,577**	**3,635**	**16.2%**
First-Line Supervisors, Production Workers	$52,530	1,610	1,280	-3.8%	588	1,162	45.9%
First-Line Supervisors, Mechanics & Installers	$60,540	890	770	-2.4%	286	596	37.1%
Machinists	$37,050	760	670	-2.1%	131	278	19.6%
Welders, Cutters, Solderers, & Brazers	$37,460	1,160	1,110	-0.7%	121	337	10.9%
Industrial Machinery Mechanics	$51,640	910	850	-1.1%	85	199	10.0%
Computer-Controlled Machine Tool Operators	$27,750	180	210	2.6%	41	93	19.5%
CNC Machine Tool Programmers	$45,850	50	60	3.1%	37	77	61.7%
Tool & Die Makers	$39,890	130	80	-7.8%	32	79	40.0%
Industrial Electrical Repairers	$49,710	350	100	-18.8%	22	49	22.0%
Millwrights	$42,809	330	90	-19.5%	14	29	15.6%
Rolling Machine Workers	$39,395	60	30	-10.9%	14	21	46.7%
Welding, Soldering, & Brazing Workers	$39,507	120	40	-16.7%	12	26	30.0%
Electricians	$45,080	1,280	1,240	-0.5%	88	249	7.1%
Inspectors, Testers, Sorters, & Weighers	$35,290	970	840	-2.4%	35	124	4.2%
Plumbers, Pipefitters, & Steamfitters	$38,090	730	460	-7.4%	34	180	7.4%
Cutting, Punching, & Press Workers	$31,770	510	460	-1.7%	18	44	3.9%
Structural Metal Fabricators & Fitters	$42,490	630	430	-6.2%	7	24	1.6%
Extruding & Drawing Machine Workers	$27,030	430	100	-21.6%	2	9	2.0%
Engineering & Design	**$77,047**	**1,650**	**2,260**	**5.4%**	**1,400**	**2,552**	**61.9%**
Industrial Engineers	$84,620	280	410	6.6%	590	1,091	143.9%
Electrical Engineers	$92,690	150	390	17.3%	275	439	70.5%
Mechanical Engineers	$86,360	200	500	16.5%	271	443	54.2%
Health & Safety Engineers	$77,890	30	120	26.0%	66	122	55.0%
Industrial Engineering Technicians	$47,610	150	180	3.1%	65	140	36.1%
Engineers, All Other	$81,100	230	140	-7.9%	56	136	40.0%
Operations Research Analysts	$77,150	210	50	-21.3%	19	40	38.0%
Mechanical Engineering Technicians	$50,560	80	70	-2.2%	10	15	14.3%
Commercial & Industrial Designers	$77,290	30	60	12.2%	6	17	10.0%
Mechanical Drafters	$52,670	180	240	4.9%	23	58	9.6%
Managerial, Business, & Operations	**$98,741**	**2,950**	**2,710**	**-1.4%**	**577**	**1,052**	**21.3%**
Purchasing Agents	$55,540	370	380	0.4%	154	267	40.5%
Architectural & Engineering Managers	$116,520	230	270	2.7%	145	231	53.7%
Purchasing Managers	$90,260	140	110	-3.9%	67	141	60.9%
Production, Planning, & Expediting Clerks	$45,030	470	450	-0.7%	66	136	14.7%
Industrial Production Managers	$95,410	370	410	1.7%	54	103	13.2%
Logisticians	$69,850	200	130	-6.9%	37	68	28.5%
Chief Executives	$157,500	1,050	780	-4.8%	47	92	6.0%
Occupational Health & Safety Specialists	$76,560	120	180	7.0%	7	14	3.9%

Knoxville, TN Metropolitan Area

Labor market information for auto-specialized occupations designated as hard-to-fill or with at least 100 workers metro-wide

MSA Criteria: Shading indicates whether an occupation is designated as "hard-to-fill"							
(1) In order to be designated as a hard-to-fill occupation, hard-to-fill postings had to be greater than or equal to 10 percent of total employment in that occupation							
(2) Groups:	Hard-to-Fill Postings greater than or equal to 200 : Hardest-to-Fill						
	Hard-to-Fill Postings greater than or equal to 50 : Harder-to-Fill						
	Hard-to-Fill Postings less than 50 and greater than 10 percent of 2012 occupation employment: Hard-to-Fill						
	Wages and Employment				Demand		
Occupation Title	Mean Annual Wage, 2012	Occupation Emp., 2006	Occupation Emp., 2012	Annualized Growth 2006-2012	Hard-to-Fill Postings, 2012	Total Job Postings, 2012	Hard-to-Fill Postings/ Emp., 2012
Production & Maintenance	**$42,269**	**14,040**	**12,890**	**-1.4%**	**1,779**	**4,604**	**13.8%**
First-Line Supervisors, Production Workers	$62,450	1,530	1,740	2.2%	585	1,253	33.6%
First-Line Supervisors, Mechanics & Installers	$58,270	1,280	1,220	-0.8%	272	689	22.3%
Welders, Cutters, Solderers, & Brazers	$30,290	1,120	550	-11.2%	211	518	38.4%
Industrial Machinery Mechanics	$46,950	460	560	3.3%	159	384	28.4%
Machinists	$35,740	1,600	890	-9.3%	110	309	12.4%
Computer-Controlled Machine Tool Operators	$32,670	210	100	-11.6%	69	176	69.0%
Tool & Die Makers	$47,270	250	100	-14.2%	64	132	64.0%
Extruding & Drawing Machine Workers	$29,440	350	190	-9.7%	29	48	15.3%
CNC Machine Tool Programmers	$39,780	50	40	-3.7%	18	50	45.0%
Lathe & Turning Machine Tool Workers	$37,830	330	40	-29.7%	5	19	12.5%
Inspectors, Testers, Sorters, & Weighers	$34,800	990	1,000	0.2%	93	238	9.3%
Electricians	$39,670	1,720	2,130	3.6%	84	349	3.9%
Plumbers, Pipefitters, & Steamfitters	$35,140	900	1,470	8.5%	41	239	2.8%
Cutting, Punching, & Press Workers	$29,120	960	610	-7.3%	8	22	1.3%
Industrial Electrical Repairers	$48,690	310	200	-7.0%	6	24	3.0%
Rolling Machine Workers	$42,290	50	130	17.3%	5	14	3.8%
Grinding, Polishing, & Buffing Workers	$30,660	320	130	-13.9%	5	14	3.8%
Welding, Soldering, & Brazing Workers	$33,850	120	120	0.0%	3	14	2.5%
Structural Metal Fabricators & Fitters	$33,780	220	190	-2.4%	1	14	0.5%
Upholsterers	$23,190	70	140	12.2%	1	17	0.7%
Electronic Equipment Repairers, Vehicles	$34,613	120	100	-3.0%	1	3	1.0%
Engineering & Design	**$77,047**	**1,650**	**2,260**	**5.4%**	**1,400**	**2,552**	**61.9%**
Industrial Engineers	$84,080	500	570	2.2%	782	1,453	137.2%
Mechanical Engineers	$83,220	340	980	19.3%	539	859	55.0%
Electrical Engineers	$92,340	270	390	6.3%	526	778	134.9%
Health & Safety Engineers	$68,830	70	180	17.0%	100	184	55.6%
Engineers, All Other	$93,280	630	830	4.7%	87	176	10.5%
Industrial Engineering Technicians	$56,310	130	100	-4.3%	72	180	72.0%
Operations Research Analysts	$57,720	100	80	-3.7%	57	102	71.3%
Mechanical Drafters	$55,900	130	160	3.5%	34	83	21.3%
Materials Engineers	$90,860	40	50	3.8%	23	38	46.0%
Electro-Mechanical Technicians	$35,938	110	50	-12.3%	21	39	42.0%
Electrical & Electronics Drafters	$53,070	150	50	-16.7%	11	21	22.0%
Engineering Technicians	$63,670	110	60	-9.6%	8	16	13.3%
Mechanical Engineering Technicians	$45,320	90	130	6.3%	10	19	7.7%
Managerial, Business, & Operations	**$100,446**	**4,260**	**4,070**	**-0.8%**	**532**	**1,083**	**13.1%**
Purchasing Agents	$57,440	490	680	5.6%	130	274	19.1%
Production, Planning, & Expediting Clerks	$51,230	780	720	-1.3%	94	185	13.1%
Architectural & Engineering Managers	$111,150	620	380	-7.8%	94	164	24.7%
Purchasing Managers	$82,560	330	250	-4.5%	71	141	28.4%
Logisticians	$61,390	80	160	12.2%	44	80	27.5%
Industrial Production Managers	$91,770	400	360	-1.7%	36	118	10.0%
Occupational Health & Safety Specialists	$78,870	150	220	6.6%	23	47	10.5%
Chief Executives	$161,370	1,410	1,300	-1.3%	40	74	3.1%

Memphis, TN-MS-AR Metropolitan Area

Labor market information for auto-specialized occupations designated as hard-to-fill or with at least 100 workers metro-wide

MSA Criteria: Shading indicates whether an occupation is designated as "hard-to-fill"							
(1) In order to be designated as a hard-to-fill occupation, hard-to-fill postings had to be greater than or equal to 10 percent of total employment in that occupation							
(2) Groups:	Hard-to-Fill Postings greater than or equal to 200 : Hardest-to-Fill						
	Hard-to-Fill Postings greater than or equal to 50 : Harder-to-Fill						
	Hard-to-Fill Postings less than 50 and greater than 10 percent of 2012 occupation employment: Hard-to-Fill						
	Wages and Employment				**Demand**		
Occupation Title	**Mean Annual Wage, 2012**	**Occupation Emp., 2006**	**Occupation Emp., 2012**	**Annualized Growth 2006-2012**	**Hard-to-Fill Postings, 2012**	**Total Job Postings, 2012**	**Hard-to-Fill Postings/ Emp., 2012**
Production & Maintenance	**$44,410**	**21,030**	**17,550**	**-3.0%**	**2,926**	**6,375**	**16.7%**
First-Line Supervisors, Production Workers	$54,410	2,610	2,330	-1.9%	1,330	2,450	57.1%
First-Line Supervisors, Mechanics & Installers	$58,350	2,210	1,850	-2.9%	901	1,797	48.7%
Industrial Machinery Mechanics	$49,890	960	970	0.2%	211	452	21.8%
Industrial Electrical Repairers	$48,500	440	270	-7.8%	78	134	28.9%
Computer-Controlled Machine Tool Operators	$38,530	310	280	-1.7%	30	94	10.7%
Model Makers, Metal & Plastic	$47,782	50	40	-3.7%	10	17	25.0%
CNC Machine Tool Programmers	$51,220	50	30	-8.2%	6	17	20.0%
Machinists	$44,390	1,090	1,180	1.3%	83	207	7.0%
Electricians	$43,440	3,030	2,570	-2.7%	78	315	3.0%
Welders, Cutters, Solderers, & Brazers	$40,570	1,410	1,000	-5.6%	58	270	5.8%
Inspectors, Testers, Sorters, & Weighers	$35,140	2,030	2,060	0.2%	50	143	2.4%
Plumbers, Pipefitters, & Steamfitters	$42,390	1,660	1,170	-5.7%	32	240	2.7%
Cutting, Punching, & Press Workers	$31,350	1,580	580	-15.4%	15	40	2.6%
Welding, Soldering, & Brazing Workers	$35,834	80	180	14.5%	8	13	4.4%
Tool & Die Makers	$43,000	320	190	-8.3%	6	17	3.2%
Maintenance Workers, Machinery	$44,550	330	470	6.1%	5	10	1.1%
Structural Metal Fabricators & Fitters	$34,820	320	380	2.9%	5	28	1.3%
Electric Motor, Power Tool Repairers	$43,360	250	190	-4.5%	3	8	1.6%
Painters, Transportation Equipment	$39,340	140	180	4.3%	3	21	1.7%
Extruding & Drawing Machine Workers	$29,580	220	110	-10.9%	2	5	1.8%
Millwrights	$43,430	180	210	2.6%	1	18	0.5%
Engineering & Design	**$71,667**	**2,630**	**3,570**	**5.2%**	**2,466**	**4,438**	**69.1%**
Industrial Engineers	$79,190	440	990	14.5%	1,441	2,503	145.6%
Operations Research Analysts	$67,340	130	440	22.5%	233	378	53.0%
Mechanical Engineers	$79,340	360	400	1.8%	198	407	49.5%
Industrial Engineering Technicians	$58,660	80	360	28.5%	167	303	46.4%
Electrical Engineers	$84,640	400	290	-5.2%	167	351	57.6%
Health & Safety Engineers	$72,910	60	50	-3.0%	128	230	256.0%
Engineers, All Other	$82,890	630	420	-6.5%	62	117	14.8%
Mechanical Drafters	$47,890	140	160	2.3%	37	79	23.1%
Commercial & Industrial Designers	$48,290	80	40	-10.9%	7	12	17.5%
Engineering Technicians	$49,630	60	120	12.2%	9	19	7.5%
Mechanical Engineering Technicians	$57,230	100	120	3.1%	3	11	2.5%
Managerial, Business, & Operations	**$94,046**	**6,900**	**6,980**	**0.2%**	**1,188**	**2,240**	**17.0%**
Purchasing Agents	$56,320	850	700	-3.2%	240	476	34.3%
Architectural & Engineering Managers	$99,530	520	430	-3.1%	180	312	41.9%
Purchasing Managers	$98,610	320	430	5.0%	178	315	41.4%
Industrial Production Managers	$98,330	570	730	4.2%	156	299	21.4%
Logisticians	$64,710	400	410	0.4%	117	224	28.5%
Occupational Health & Safety Specialists	$62,940	80	210	17.5%	82	140	39.0%
Production, Planning, & Expediting Clerks	$43,580	1,540	2,160	5.8%	179	366	8.3%
Chief Executives	$170,760	2,620	1,910	-5.1%	56	108	2.9%

Nashville-Davidson–Murfreesboro–Franklin, TN Metropolitan Area

Labor market information for auto-specialized occupations designated as hard-to-fill or with at least 100 workers metro-wide

MSA Criteria: Shading indicates whether an occupation is designated as "hard-to-fill"							
(1) In order to be designated as a hard-to-fill occupation, hard-to-fill postings had to be greater than or equal to 10 percent of total employment in that occupation							
(2) Groups:	Hard-to-Fill Postings greater than or equal to 200 : Hardest-to-Fill						
	Hard-to-Fill Postings greater than or equal to 50 : Harder-to-Fill						
	Hard-to-Fill Postings less than 50 and greater than 10 percent of 2012 occupation employment: Hard-to-Fill						
	Wages and Employment				**Demand**		
Occupation Title	**Mean Annual Wage, 2012**	**Occupation Emp., 2006**	**Occupation Emp., 2012**	**Annualized Growth 2006-2012**	**Hard-to-Fill Postings, 2012**	**Total Job Postings, 2012**	**Hard-to-Fill Postings/ Emp., 2012**
Production & Maintenance	**$42,482**	**30,230**	**25,820**	**-2.6%**	**4,060**	**10,021**	**15.7%**
First-Line Supervisors, Production Workers	$55,240	4,590	3,290	-5.4%	1,589	3,133	48.3%
First-Line Supervisors, Mechanics & Installers	$57,320	2,900	2,400	-3.1%	837	1,893	34.9%
Industrial Machinery Mechanics	$43,910	1,290	1,360	0.9%	284	630	20.9%
Machinists	$39,110	1,940	1,170	-8.1%	195	541	16.7%
Welders, Cutters, Solderers, & Brazers	$38,410	1,390	1,030	-4.9%	155	560	15.0%
Tool & Die Makers	$45,210	810	740	-1.5%	155	315	20.9%
Computer-Controlled Machine Tool Operators	$40,230	570	250	-12.8%	73	230	29.2%
Millwrights	$41,650	320	140	-12.9%	15	25	10.7%
CNC Machine Tool Programmers	$43,450	70	60	-2.5%	14	42	23.3%
Upholsterers	$23,940	50	90	10.3%	12	48	13.3%
Electricians	$42,610	2,820	3,010	1.1%	197	769	6.5%
Inspectors, Testers, Sorters, & Weighers	$36,950	2,650	3,080	2.5%	188	512	6.1%
Cutting, Punching, & Press Workers	$33,240	2,430	1,950	-3.6%	137	371	7.0%
Plumbers, Pipefitters, & Steamfitters	$47,460	3,140	1,650	-10.2%	102	506	6.2%
Industrial Electrical Repairers	$45,900	180	430	15.6%	24	55	5.6%
Extruding & Drawing Machine Workers	$32,630	340	500	6.6%	18	37	3.6%
Lathe & Turning Machine Tool Workers	$31,793	590	160	-19.5%	14	51	8.8%
Rolling Machine Workers	$34,000	140	330	15.4%	11	45	3.3%
Painters, Transportation Equipment	$39,350	130	250	11.5%	8	87	3.2%
Electric Motor, Power Tool Repairers	$31,710	130	110	-2.7%	7	18	6.4%
Structural Metal Fabricators & Fitters	$30,480	460	610	4.8%	3	26	0.5%
Multiple Machine Tool Workers	$31,700	310	1,010	21.8%	2	15	0.2%
Grinding, Polishing, & Buffing Workers	$31,180	470	230	-11.2%	2	20	0.9%
Engineering & Design	**$71,353**	**4,810**	**4,940**	**0.4%**	**3,678**	**6,739**	**74.5%**
Industrial Engineers	$76,870	1,030	1,340	4.5%	1,769	3,114	132.0%
Mechanical Engineers	$77,100	1,070	740	-6.0%	579	1,034	78.2%
Electrical Engineers	$83,330	590	650	1.6%	490	867	75.4%
Operations Research Analysts	$67,440	160	430	17.9%	329	601	76.5%
Engineers, All Other	$75,080	570	480	-2.8%	156	305	32.5%
Health & Safety Engineers	$74,940	40	150	24.6%	127	255	84.7%
Industrial Engineering Technicians	$51,400	310	240	-4.2%	123	311	51.3%
Mechanical Drafters	$48,800	310	250	-3.5%	39	95	15.6%
Materials Engineers	$73,250	50	50	0.0%	11	21	22.0%
Commercial & Industrial Designers	$64,660	110	190	9.5%	16	38	8.4%
Engineering Technicians	$53,380	260	170	-6.8%	14	38	8.2%
Managerial, Business, & Operations	**$102,415**	**8,980**	**9,100**	**0.2%**	**1,894**	**3,632**	**20.8%**
Purchasing Agents	$57,920	1,200	1,250	0.7%	435	888	34.8%
Purchasing Managers	$77,210	680	520	-4.4%	329	611	63.3%
Logisticians	$58,880	430	170	-14.3%	293	527	172.4%
Production, Planning, & Expediting Clerks	$38,510	1,680	1,840	1.5%	277	543	15.1%
Architectural & Engineering Managers	$108,180	730	680	-1.2%	232	406	34.1%
Industrial Production Managers	$85,980	750	800	1.1%	131	282	16.4%
Occupational Health & Safety Specialists	$60,220	100	240	15.7%	66	108	27.5%
Chief Executives	$161,600	3,410	3,600	0.9%	131	267	3.6%

APPENDIX E. TENNESSEE R&D INSTITUTIONS

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the largest R&D facility in Tennessee. ORNL emphasizes applied R&D with commercialization pathways; in 2011 ORNL surpassed General Electric as the top U.S. research facility for *R&D* magazine's R&D 100 awards for the most significant technological innovations.[1] It has increased R&D funding by 55 percent since 2007 to over $1.7 billion.

ORNL creates on average 252 new research agreements annually, which are together worth $28.6 million. While ORNL has a national constituency, there are a number of regional opportunities for Tennessee auto firms, including the Work For Others program and other technology-transfer initiatives. The most likely opportunities for collaboration exist within ORNL's Carbon Fiber Technology Facility and its Manufacturing Demonstration Facility, which is a national research leader in automotive battery technology and additive manufacturing.

Year	2007	2008	2009	2010	2011	2012
R&D expenditures ($ millions)	$1,100.0	$1,300.0	$1,475.0	$1,650.0	$1,650.0	$1,720.0
Federal Laboratory Consortium for Technology Transfer awards	1	1	2	1	2	1
R&D awards	6	6	8	9	7	10
Licenses	21	29	25	35	31	28
Income from licenses ($ thousands)	$2,938.80	$2,570.50	$1,406.20	$2,071.90	$2,131.50	$2,689.10
Patents issued	40	18	35	72	54	74
Total new research agreements	304	304	267	292	264	221
Non-federal Work with Others agreements	113	170	80	97	90	107
Dollar value of non-federal Work with Others agreements ($ millions)	N/A	N/A	N/A	$25.60	$28.70	$31.50
User agreements	180	120	178	176	150	100

University of Tennessee

The University of Tennessee-Knoxville has a university-wide goal of becoming a top 25 public research institution. In order to meet this goal, UT steadily increased R&D expenditures by 35 percent between 2007 and 2011 and established a number of research-oriented programs. However, although patents have increased by nearly 80 percent over the last five years,

certain research outcome indicators have not grown at similar rates. For example, licenses and license income have grown by 12.5 percent and 13.5 percent, respectively.

The University's Governor's Chairs program recruits prominent faculty for joint appointments to UT and Oak Ridge National Laboratory. Although the 11 current Governor's Chairs faculty members have core competencies in fields largely unrelated to the auto industry, the university has recently hired Sudarsanam Babu, as the Governor's Chair for Advanced Manufacturing. Babu should be a critical faculty member in UT's manufacturing R&D. In addition, UT is constructing a 200-acre Innovation Campus for material science and other STEM research fields.[2]

Year	2007	2008	2009	2010	2011
R&D expenditures ($ millions)	$238.55	$246.40	$284.21	$286.28	$321.94
Public funding ($ millions)	$113.70	$108.09	$148.52	$150.66	$168.07
Industry funding ($ millions)	$35.85	$38.25	$34.03	$34.31	$44.65
Licenses	8	13	11	11	9
Income from licenses ($ millions)	$1.19	$3.88	$1.61	$0.43	$1.35
Disclosures	66	97	84	91	87
New patent applications	56	64	146	96	70
Patents issued	10	15	16	22	18
Startups	2	2	2	4	4

Vanderbilt University

Vanderbilt University is the largest research university in Tennessee. Between 2007 and 2011 Vanderbilt increased its R&D expenditures by 32 percent, nearly 85 percent of which was publicly funded. However, disclosures and patents issued increased by only 16 percent and 14.8 percent, respectively.

Vanderbilt's core competency is within the life sciences and medical device research; over 80 percent of available technologies for license are in the life sciences or medical devices, and 56 percent of invention disclosures originate in Vanderbilt's medical center.[3] At the same time, Vanderbilt also has a number of programs that emphasize nuclear, aerospace, and advanced computer science.[4] However, with little emphasis on research fields relevant to auto, Vanderbilt has few relationships with the Tennessee automakers or their supply chains.

Year	2007	2008	2009	2010	2011
R&D expenditures ($ millions)	$411.1	$444.3	$457.4	$491.6	$543.1
Public funding ($ millions)	$324.4	$348.6	$357.4	$397.7	$458.4
Industry funding ($ millions)	$18.0	$21.2	$19.3	$19.5	$19.2
Licenses	41	47	42	42	47
Income from licenses ($ millions)	$9.0	$8.3	$11.3	$5.6	$10.0
Disclosures	144	134	150	133	167
New patent applications	67	69	64	72	83
Patents issued	27	16	17	19	31
Startups	4	4	1	0	0

ENDNOTES

CHAPTER II

[1] Since the late 1970s, Tennessee governors have worked with the state legislature to cultivate a strong automotive industry in the state. Working with then-State Speaker of the House Ned McWherter, Gov. Alexander convinced Nissan to build its first American manufacturing facility in Smyrna, which was soon followed by the Saturn plant in Spring Hill. Gov. McWherter's tenure brought continued industry growth, with a $490 million expansion of Nissan's Smyrna plant, a new $500 million Nissan engine plant in Decherd, and a $30 million Honda parts redistribution center in Loudon. During Gov. Don Sundquist's time in office, Nissan deepened its investment in Tennessee, dedicating over $1 billion to expand operations in Smyrna and Decherd. Richard Parker, "Lamar Alexander," *Albuquerque Journal*, November 26, 1995; Shera Gross, "Nissan Plans $490 Million Expansion," Associated Press, April 3, 1989; Phil West, "Japanese Automaker Plans $500 Million U.S. Engine Plant," Associated Press, January 18, 1991; Pam Park, "Loudon Lands Honda Parts Center $30 Million Facility Slated For Early '96 Opening," *Knoxville News-Sentinel*, July 25, 1994.

[2] Bill Haslam, Inaugural Address, January 15, 2011.

CHAPTER III

[1] Using Census Bureau definitions, the auto sector consists of three separate industries: motor vehicle manufacturing (NAICS 3361), motor vehicle body and trailer manufacturing (NAICS 3362), and motor vehicle parts manufacturing (NAICS 3363). Only two of these component industries—NAICS codes 3361 and 3363—meet the necessary criteria to be designated "advanced industries." When the auto industry is discussed in this report within the context of advanced industries, only the two "advanced" component industries are being considered. In all other instances—with the exception of the establishment-based analysis that intentionally abandons conventional NAICS codes in favor of a looser, more organic, and cluster-based approach to industry definition and analytics—auto is synonymous with the group of all three motor-vehicle-related NAICS codes together.

For more information on the definition of advanced industries see the corresponding sidebar in Chapter II and the report "Advanced Industries: Defining America's Competitiveness" (Washington: Brookings Institution, forthcoming 2014).

[2] Peer states were selected by analyzing location quotients and by using input from Tennessee partners.

[3] As noted above, the automobile industry in this section of the report is usually defined as the compilation of three motor-vehicle-related NAICS codes: 3361 (motor vehicle manufacturing), 3362 (motor vehicle body and trailer manufacturing), and 3363 (motor vehicle parts manufacturing). Only two of these industries, 3361 and 3363, meet the criteria of advanced industries, however. Hence the breakout here. For more on Brookings' definition of advanced industries, see the sidebar in Chapter II.

[4] Brookings analysis of Moody's Analytics data through December 2012.

[5] Brookings analysis of Moody's Analytics data.

[6] Brookings analysis of Moody's Analytics data. Values in chained 2005 dollars.

[7] See, for example, Nick Miroff, "With Mexican Auto Manufacturing Boom, New Worries," *Washington Post*, July 1, 2013; Center for Automotive Research, "Accelerating the Growth of the U.S. Automotive Manufacturing Industry in the Southern United States" (Ann Arbor, 2012); PricewaterhouseCoopers Mexico, "Doing Business in Mexico: Automotive Industry" (2013); and Thomas Klier and James Rubenstein, "The Growing Importance of Mexico in North American Auto Production," Chicago Fed Letter No. 310 (Federal Reserve Bank of Chicago, 2013)

[8] Brookings analysis of Moody's Analytics data. Peaks are defined as the highest level of employment reached in a year since (and including) 2002. Potential explanations for Tennessee's persisting employment gap include an increased reliance of automakers on flexible pools of contract workers technically considered part of the employment services industry (NAICS 5613) even if their primary place of work is a motor vehicle manufacturing establishment, or slow ramp-ups at select large facilities like GM's Spring Hill plant. There is no reason to believe that such factors affect industry employment in Tennessee disproportionately, however.

[9] Neal Boudette and Jeff Bennet, "U.S. Car Sales Soar to Pre-Slump Level," *Wall Street Journal*, September 4, 2013, and Michael Fletcher, "Auto Sales Sizzle Amid Tepid Recovery," *Washington Post*, September 4, 2013.

[10] Sean McAlinden and Yen Chen, "After the Bailout: Future Prospects for the U.S. Auto Industry" (Ann Arbor: 2012), and Center for Automotive Research, "CAR 3rd Quarter U.S. Sales, Production, and Employment Outlook" (Ann Arbor: 2013).

[11] Sean McAlinden and Yen Chen, "After the Bailout," and Neal Boudette and Jeff Bennet, "U.S. Car Sales Soar to Pre-Slump Level."

[12] Bureau of Economic Analysis Input Output Tables, "The Use of Commodities by Industries" (2011). The motor vehicle industry is here defined as NAICS codes 3361, 3362, and 3363.

[13] Brookings utilized lists of suppliers from industry intelligence providers ELM Analytics and MarkLines to identify firms and establishments.

[14] Brookings adopted the Small Business Administration's establishment size classifications of 0-99 workers (small), 100 to 499 workers (medium), and 500 or more workers (large)

[15] "Nissan to Boost Americas Production Capacity to More Than 2 Million Units in 2014," *Wall Street Journal*, August 26, 2013.

[16] See among others Thomas Klier and James Rubenstein, *Who Really Made Your Car? Restructuring and Geographic Change in the Auto Industry* (Kalamazoo, MI: W.E. Upjohn Institute for Employment Research, 2008), and Thomas Klier and Daniel McMillen, "Evolving Agglomeration in the U.S. Auto Supplier Industry," *Journal of Regional Science* 48 (1) (2008): 245–267.

[17] Brookings' analysis relies on Dun & Bradstreet's identification of a business establishment as R&D-conducting and may accordingly be subject to error.

[18] Timothy Sturgeon, Johannes Van Biesebroeck, and Gary Gereffi, "Value Chains, Networks, and Clusters: Reframing the Global Automotive Industry," Working Paper 08-002 (Cambridge: Massachusetts Institute of Technology Industrial Performance Center, 2008).

[19] Subsidiary headquarters count as company headquarters for this analysis even if an ultimate parent or holding company is located elsewhere.

[20] Totals are not value-added but instead gross output, or total value including intermediates embedded in the product. Hence the value of final exports is larger than total industry GDP (or value-added) in Tennessee. This estimate exceeds the $4.6 billion figure given by the International Trade Administration (ITA) due to differences in methodology. The ITA tabulates state export data based on origin of movements, which bias the numbers in favor of port and border states where shipments from other states get consolidated before export abroad. The bias is most clearly demonstrated in the data for Texas: In ITA data Texas exported $18.3 billion worth of auto-related goods in 2012, or 13.8 percent of total U.S. auto exports, even though its share of total U.S. auto-related GDP was only 6.5 percent. In order to tie exports to the physical loci of production more accurately, Brookings relied on freight flows data measuring the physical shipment of commodities in an industry by value and weight combined with an allocation of exports according to state share of national industry production. Sources: Brookings analysis of Moody's Analytics, BLS, and Census data and Brookings and EDR analysis of U.S. Department of Transportation's Freight Analysis Framework (FAF) data. For more information on methodologies see Appendix A of the Brookings' report "Export Nation 2012" and the forthcoming Brookings report "Metropolitan Freight Flows" (title subject to change; forthcoming October 2013).

[21] "Video Report: Nissan U.S. Manufacturing on Track to Nearly Double Export Markets by End of 2015" (Irvine, CA: Nissan North America, 2013).

[22] International Trade Administration, "Trends in U.S. Vehicle Exports" (Washington: U.S. Department of Commerce, 2013) and "Video Report: Nissan U.S. Manufacturing on Track to Nearly Double Export Markets by End of 2015."

[23] International Trade Administration, "Trends in U.S. Vehicle Exports."

[24] Dun & Bradstreet identifies establishments that engage in exporting with an "exporter" flag. Given D&B's telephonic survey-based methodology and known shortcomings in recency and coverage, though, there is reason to suspect that D&B underestimates the number of establishments producing for export. Brookings visited the websites of firms identified as exporting and found that D&B's flags were generally verifiable; in other words, D&B did not wrongly tag firms as exporters (likely because D&B requires firms and establishments to self-identify). As such and assuming that any error or downward bias is systematic and does not disproportionately affect Tennessee, Brookings considers this measure a useful, if rough, benchmark of the export propensity of establishments in each state.

[25] As of early 2013 news reports and expansion announcements at Nissan suggest that automakers' employment numbers have risen over the course of the year; automakers' share of metropolitan-area industry employment will also have risen only if automakers added jobs at a faster rate than suppliers.

CHAPTER IV

[1] Robert Atkinson, Luke Stewart, Scott Andes, and Stephen Ezell, "Worse Than the Great Depression: What Experts Are Missing About American Manufacturing Decline" (Washington: Information Technology & Innovation Foundation, 2012).

[2] Chris Isidore, "7.9 Million Jobs Lost—Many Forever," *CNN Money*, July 2, 2010.

[3] Jeff Rosen and Kimberly DuBord, "State of the U.S. Motor Vehicle Industry: 2012" (Michigan: Briefing Research, 2012).

[4] Carlos Gomes, "Global Auto Report" (New York: Scotiabank, 2013).

[5] Moran Zhang, "Global Auto Industry Outlook: Auto Sales to Grow 6% in 2012" *International Business Times*, September 14, 2012.

[6] Kelly Thomas, "The Automotive Supply Chain in the New Normal" (New York: JDA, 2012).

[7] McKinsey & Company, "The Future of the North American Automotive Supplier Industry: Evolution of Component Costs, Penetration, and Value Creation Potential Through 2020" (2012).

[8] Robert Wright, "U.S. Auto Industry Shrugs Off Uncertainty," *Financial Times,* January 3, 2013; Al Bredenberg, "Bullish U.S. Auto Industry Plans New Hiring," *Industry Market News,* August 7, 2012.

[9] United Nations Conference on Trade and Development, "World Investment Report 2012" (2013).

[10] Ibid.

[11] "U.S. Car and Truck Sales, 1931-2012," available at http://wardsauto.com/keydata/historical/UsaSa01summary (March 2013).

[12] Report Linker, "Global Auto Component Industry 2012-2017: Trend, Profit, and Forecast Analysis" (2012).

[13] "Bureau of Labor Statistics," available at www.bls.gov/ (March 2013).

[14] Kristin Dziczek, "Supplier Employment Trends" (Detroit: Center for Automotive Research, 2012).

[15] ATKearney, "India's Auto Component Suppliers: New Frontiers in Growth" (2012).

[16] PriceWaterhouseCoopers, "Consolidation in the Global Automotive Supply Chain" (2012).

[17] Ibid.

[18] Arthur Wang, Wenkan Liao, Arnt-Philipp Hein, "Bigger, Better, Broader: A Perspective on China's Auto Market in 2020" (Washington: McKinsey & Company, 2012).

[19] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[20] "ITA Trade Express," available http://tse.export.gov/TSE/TSEhome.aspx (March 2013).

[21] While a number of recent news reports have suggested the end of the resource "supercycle"—the period of massive commodity price rises and volatility beginning in the 21st century—the market consensus is that commodity prices are not set to decline anytime soon. See "Resource Revolution: Tracking Global Commodity Markets" (Washington: McKinsey Global Institute, 2013) and "Everyday Higher Prices," *The Economist*, February 24, 2011.

[22] Klier and Rubenstein, *Who Really Made Your Car?: Restructuring and Geographic Change in the Auto Industry*.

[23] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[24] Jim Witkin, "A Push to Make Motors With Fewer Rare Earths" *New York Times*, April 20, 2012.

[25] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[26] Ibid.

[27] Ibid.

[28] Center for Automotive Research, "The U.S. Automotive Market and Industry in 2025" (2011).

[29] Ernst & Young, "The Quest for Telematics 4.0: Creating Sustainable Value Propositions Supporting Car-Web Integration" (2012).

[30] Ibid.

[31] Accenture, "Perspectives on In-Vehicle Infotainment Systems and Telematics: How Will They Figure In Consumers' Vehicle Buying Decisions" (2011).

[32] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[33] Robert Wright, "US Auto Industry Shrugs Off Uncertainty."

[34] Tom Morrison, Emily DeRocco, and others, "Boiling Point? The Skills Gap in U.S. Manufacturing" (Deloitte and the Manufacturing Institute, 2011).

[35] Center for Automotive Research, "Automotive Technology: Greener Products, Changing Skills: Powertrain & Fuel Report," (Ann Arbor: 2011).

[36] For example, see "Car Mechatronics" available at www.chattanoogastate.edu/engineering-technology/partnerships/vw-academy/car-mechatronics-aas.html (September 2013).

[37] Sean McAlinden, Kristin Dziczek, and others, "Beyond the Big Leave: The Future of U.S. Automotive Human Resources" (Ann Arbor: Center for Automotive Research, 2008).

[38] Ibid.

[39] Morrison, DeRocco, and others, "Boiling Point? The Skills Gap in U.S. Manufacturing."

[40] Ibid.

[41] McAlinden, Dziczek, and others, "Beyond the Big Leave."

[42] Boston Consulting Group, "Rethinking Automotive Purchasing: From Price Pressure to Partnership" (2003).

[43] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[44] Ibid.

[45] Center for Automotive Research, "Automotive Technology."

[46] McKinsey & Company, "The Future of the North American Automotive Supplier Industry."

[47] Center for Automotive Research, "Automotive Technology."

[48] KPMG, "KPMG's Global Automotive Executive Survey 2012: Managing Growth While Navigating Uncharted Routes," available at www.kpmg.com/GE/en/IssuesAndInsights/ArticlesPublications/Documents/Global-automotive-executive-survey-2012.pdf (March 2013).

[49] PriceWaterhouseCoopers, "Consolidation in the Global Automotive Supply Industry."

CHAPTER V

[1] Access to interstate highways is especially important for foreign transplants like Nissan, since foreign suppliers (as compared to domestic suppliers) tend to prefer locating near interstate highways. For more information see Thomas Klier, Paul Ma, and Daniel P. McMillen, "Comparing Location Decisions of Domestic and Foreign Auto Supplier Plants," Working Paper 2004-27 (Federal Reserve Bank of Chicago, 2004).

[2] Federal Highway Administration, "Our Nation's Highways 2008," (2008); Dave Flessner, "City, VW Have a Lot Riding on Passat," *Chattanooga Times Free Press*, January 16, 2011; Carole Robinson, "State Route 840 Ribbon Cutting Opens Long-Awaiting Connection," *Williamson Herald*, November 7, 2012.

[3] CNBC, "America's Top States for Business 2013" (2013), available at www.cnbc.com/id/100614146 (September 2013). CNBC rates each state's transportation system based on the quantity of goods shipped by air, waterways, roads, and rail; the availability of air travel; the quality of roads, bridges, and the water supply; and commuting times.

[4] Area Development Site and Facility Planning, "Top States for Doing Business," available at www.areadevelopment.com/Top-States-for-Doing-Business (August 2013).

[5] Cambridge Systematics, "Chattanooga Regional Freight Profile" (2011), available at www.camsys.com/pubs/Chattanooga_Region_Freight_Profile.pdf (September 2013).

[6] "2013 Business Facilities Rankings Report—State Rankings," *Business Facilities*, August 5, 2013, available at http://businessfacilities.com/cover-story-2013-business-facilities-rankings-report-state-rankings (August 2013).

[7] U.S. Census Bureau, *Statistical Abstract of the United States*, Table 728 "Cost of Living Index—Selected Urban Areas, Annual Average: 2010." Data exclude taxes, and Tennessee levies some of the highest sales taxes in the country to offset its lack of an income tax.

[8] Overall, Tennesseans enjoy one of the lowest overall individual tax burdens in the nation, paying about 7.7 percent of average income in taxes in contrast to the national average of 9.9 percent and peer-state average of 9.0 percent. For more information see Tax Foundation, "State and Local Tax Burdens: All Years, One State, 1977-2010" (2012). Other indices used include Tax Foundation, "Tax Freedom Day" (2012) and Fraser Institute, "Economic Freedom of North America 2012" (2012). Of Tennessee's peer states, only Texas does not levy a state income tax. Corporation for Enterprise Development, "Assets and Opportunities Scorecard" (2013).

[9] See Tax Foundation, "State Debt Per Capita, Fiscal Year 2010," available at http://taxfoundation.org/article/state-debt-capita-fiscal-year-2010 (September 2013).

[10] Information Technology and Innovation Foundation, "The 2012 State New Economy Index" (Washington: 2012). According to ITIF, migration of knowledge workers is measured as the average educational attainment in years of schooling of recent migrants aged 25 and over.

[11] Information Technology and Innovation Foundation, "The 2012 State New Economy Index" (Washington: 2012).

[12] U.S. Census Bureau, "2011 American Community Survey" (Washington: 2012).

[13] Migration Policy Institute, "MPI Data Hub" (Washington: 2012), available at www.migrationinformation.org/datahub/state.cfm?ID=TN#1 (September 2013).

[14] Email correspondence with Tennessee Department of Economic and Community Development.

[15] For more information on this new initiative, see the Jobs4TN website at www.tn.gov/ecd/Jobs4TN.html (August 2013). Further detail on the four key strategies of Jobs4TN can be found at www.tn.gov/ecd/pdf/Jobs4TN_PowerPoint.pdf (August 2013). Tennessee Department of Economic and Community Development, "Jobs4TN Plan," presentation, available at www.tn.gov/ecd/pdf/Jobs4TN_PowerPoint.pdf (September 2013). State of Tennessee, "TNForward: Top to Bottom Review" (2013); Bruce Katz and Mark Muro, "The Cluster Moment: Getting Real About the Economy," *UpFront*, September 21, 2010, available at www.brookings.edu/blogs/up-front/posts/2010/09/21-innovation-muro-katz (August 2013).

[16] Tennessee Department of Economic and Community Development, "Regional Strategic Plans" (2011), available at www.tn.gov/ecd/Directors/pdf/Regional_Strategic_Plans/Exec_Summary.pdf (August 2013).

[17] Tennessee Department of Economic and Community Development, "Jobs4TN Rollout" (2011), available at www.tn.gov/ecd/Jobs4TN.html (August 2013).

[18] Interview with Danielle Mezera, Assistant Commissioner of Career and Technical Education, State of Tennessee, December 18, 2013.

[19] Tennessee Student Assistance Corporation, "Tennessee Education Lottery Scholarship Program," available at www.tn.gov/collegepays/mon_college/lottery_scholars.htm (August 2013).

[20] Data from the Tennessee Department of Labor and Workforce Development.

[21] *Complete College Tennessee Act of 2010*, Senate Bill No. 7006, First Extraordinary Session, Public Chapter No. 3 (State of Tennessee, 2010), available at www.tennessee.edu/system/academicaffairs/docs/CCTA_signed_legislation.pdf (September 2013).

[22] Bill Haslam, "State of the State Address: Why Tennessee Is Different," January 28, 2013, available at www.tn.gov/stateofthestate/files/2013/01-28-13%20State%20of%20the%20State%20Address%20-%20FINAL.pdf (May 2013).

[23] Jobs for the Future, "Pathways to Prosperity Network," available at www.jff.org/sites/default/files/u3/PTPN_FourPager_031513.pdf (September 2013); interview with Nancy Hoffman, Vice President and Senior Advisor, Jobs for the Future, March 29, 2013.

[24] Paul Bradley, "Cover Story: A Model for Success," *Community College Weekly*, February 6, 2012, available at www.ccweek.com/news/templates/template.aspx?articleid=2912&zoneid=7 (August 2013).

[25] Complete College America, "A Working Model for Student Success: The Tennessee Technology Centers," (Washington: 2010), available at www.completecollege.org/docs/Tennessee%20Technology%20Centers-%20A%20Preliminary%20Case%20Study(1).pdf (August 2013).

[26] Institute for a Competitive Workforce and the National Career Pathways Network, "Thriving in Challenging Times: Connecting Education to Economic Development Through Career Pathways" (2012); AMTEC, "National Center for Excellence in Automotive Manufacturing," available at www.autoworkforce.org/Our_Partners (May 2013).

[27] National Science Foundation, "National Science Foundation Research and Development: State & Local Government" (2013), available at www.nsf.gov/statistics/showpub.cfm?TopID=8&SubID=41 (August 2013).

[28] See "autoXLR8R Frequently Asked Questions," available at http://smtec.com/autoxlr8r/faqs (September 2013).

[29] LaunchTN, "Annual Report to Governor and General Assembly" (November 2012), available at www.launchtn.org/wp-content/uploads/2012/08/2012-Annual-Report-to-Governor-Final.pdf (September 2013).

[30] CNBC, "America's Top States for Business 2012."

[31] Raymond Keating, "Business Tax Index 2013: Best to Worst State Tax Systems for Entrepreneurship and Small Business" (Washington: Small Business Council, 2013).

[32] "Location Matters: A Comparative Analysis of State Tax Costs on Business" (Washington: Tax Foundation and KPMG, 2012). In particular, new R&D facilities and labor-intensive manufacturing facilities rank low in Tennessee due to the state's high sales tax, mid-level corporate tax rate, double-weighted sales factor, and lack of an R&D tax credit.

[33] Those Tennessee peer states that provide an R&D tax credit are Georgia, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, South Carolina, and Texas. See "State R&D Taxes," available at www.warner-robinson.com/rd-tax-credit/state-benefits (May 2013).

[34] A number of studies show that the R&D tax credit induces higher levels of investments. For example, see: Australian Bureau of Industry Economics, "R&D, Innovation, and Competitiveness: An Evaluation of the R&D Tax Concession" (Canberra: Australian Government Publishing Service, 1993); Marcel Dagenais, Pierre Mohnen, and Pierre Therrien, "Do Canadian Firms Respond to Fiscal Incentives to Research and Development?" Working Paper (Montreal: CIRANO, 1997); Mark Parsons and Nicholas Phillips, "An Evaluation of the Federal Tax Credit for Scientific Research and Experimental Development," Working Paper (Department of Finance Canada, 2007); Bronwyn Hall and Jon van Reenen, "How Effective Are Fiscal Incentives for R&D? A Review of the Evidence," *Research Policy* 29 (2000): 449–469; and Dominique Guellec and Bruno van Pottelsberghe de la Potterie, "The Impact of Public R&D Expenditure on Business R&D," *Economics of Innovation and New Technology* 12 (3) (2003): 225–243. Other papers show that state R&D credits in particular support employment and R&D in states. See, for example, Yujeung Ho, "Evaluating the Effects of State R&D Tax Credits," Ph.D. dissertation, University of Pittsburgh, 2006. Other papers, while acknowledging state R&D credits support state R&D, argue that much of this R&D is simply due to relocation among firms and does not necessarily produce more R&D in aggregate. See, for example, Daniel Wilson, "Beggar thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits," Working Paper Series (Federal Reserve Bank of San Francisco, 2007).

[35] "Location Matters: A Comparative Analysis of State Tax Costs on Business."

[36] Unemployment insurance tax in Tennessee is allocated based on the age and type of firm. Younger firms pay a baseline of 2.7 percent in UI tax, which declines after a firm has been in business for three years. Firms over three years old can qualify for the lowest rate, which is 0.5 percent or 20 times less than the maximum rate (10 percent) that new firms pay. UI tax rates are also affected by layoffs, with firms in sectors with above-average layoffs over the past year paying higher UI tax rates than other firms. For example, in 2012 each manufacturing three-digit NAICS code paid a different rate depending upon the number of layoffs it suffered in the prior year. NAICS codes 331, 332, and 333 paid 2.7 percent, 6.1 percent, and 8.6 percent, respectively.

[37] Gregory Tassey, "Rationales and Mechanisms for Revitalizing US Manufacturing R&D Strategies," *Journal of Technology Transfer* 35 (3) (2010): 283–333.

[38] See, for example, Mark Muro and Kenan Fikri, "Job Creation on a Budget: How Regional Industry Clusters Can Add Jobs, Bolster Entrepreneurship, and Speak Innovation" (Washington: Brookings Institution, 2011).

[39] A number of studies have shown that a greater number of trade agreements with large auto markets would help reduce existing trade barriers. For example, discussions over a Trans-Pacific Partnership Agreement with Japan have already resulted in Japan agreeing to reduce U.S. import tariffs. See William Cooper and Mark Manyin, "Japan's Possible Entry into the Trans-Pacific Partnership and Its Implications" (Washington: Congressional Research Service, 2013). Mexico is a prime example of a competitor that has leveraged free trade agreements to support its auto industry. See M. Angeles Villarreal, "Mexico's Free Trade Agreements" (Washington: Congressional Research Service, 2009).

[40] James Harrison, "Sen. Alexander Says Free Trade Agreements Would Mean Jobs to Tennessee," *Chattanooga Times,* February 21, 2014. Technically, Mexico and Brazil do not have a free trade agreement. Instead, the two countries have a 2002 agreement that allows free trade of autos between the two nations. However, in May 2012 Brazil altered the arrangement by introducing a three-year quota limit on Mexican auto imports. The agreement puts quotas on Mexican automobile exports to Brazil for three years equal to $1.45 billion, $1.56 billion, and $1.64 billion in 2013–2015. See Laurence Iliff and Gerald Jeffris, "Mexico and Brazil Fix Trade Spat on Cars," *The Wall Street Journal*, March 15, 2012.

[41] See, for example, Howard Schneider, "NSA Revelations, Modified Wheat Cast a Pall Over Trade Talks With Europe," *Washington Post,* June 13, 2013.

[42] Tennessee Department of Economic and Community Development, "Tennessee International Division Strategy," May 2013.

[43] National Center for Education Statistics, "National Assessment of Educational Progress" (2011), available at http://nces.ed.gov/nationsreportcard (August 2013); Corporation for Enterprise Development, "Assets and Opportunities Scorecard" (2011). In 2011, 29.6 percent of adults in Tennessee had at least a two-year college degree and 23.6 percent had at least a four-year degree, ranking ninth and eighth respectively among peer states and 44th and 43rd respectively among all states.

[44] Brookings analysis of IPEDS data. For this data series, STEM-related fields of study are defined as: Agricultural Sciences, Applied Technology, Chemistry, Computer Science, Engineering, Geosciences, Life/Biological Sciences, Mathematics, and Physics/Astronomy.

[45] Brookings analysis of the 2011 American Community Survey. For this data series, STEM-related fields of study are defined as: Biological, Agricultural, and Environmental Sciences; Computers, Mathematics, and Statistics; Physical and Related Science; Engineering; and Science- and Engineering-Related Fields.

[46] In 2011, a survey of manufacturing employers by Deloitte and the Manufacturing Institute saw "67 percent of respondents reporting a moderate to severe shortage of available, qualified workers and 56 percent anticipating the shortage to grow worse in the next three to five years." This survey also found that "5 percent of current jobs at respondent manufacturers are unfilled due to a lack of qualified candidates." See Morrison, DeRocco, and others, "Boiling Point? The Skills Gap in U.S. Manufacturing."

[47] A recent report by the Boston Consulting Group asserts that near-term fears of a skills crisis in manufacturing are "overblown," noting that "quite often, the skilled workers are available—just not at the price employers are willing to pay." The report also points to flaws in firm recruiting practices as a source for the perceived skilled worker shortage. See Harold L. Sirkin, Michael Zinser, and Justin Rose, "The U.S. Skills Gap: Could It Threaten a Manufacturing Renaissance?" (Boston Consulting Group, 2013). Adam Davidson has argued that employer difficulty in finding qualified workers stems in large part from firms' unwillingness to pay higher wages rather than a true skills gap. See Adam Davidson, "Skills Don't Pay the Bills," *New York Times*, November 20, 2012.

[48] Kristin Dziczek and others, "Driving Workforce Change: Regional Impact and Implications of Auto Industry Transformation to a Green Economy" (Driving Change: Greening the Automotive Workforce, 2011); McAlinden, Dziczek, and others, "Beyond the Big Leave"; Susan Cantrell, James Robbins, and David Smith, "Solving the Skills Crisis in the Automotive Industry," Accenture Outlook Point of View (February 2011); Susan Helper and others, "The U.S. Auto Supply Chain at a Crossroads: Implications of an Industry in Transformation," Case Western University and Driving Change: Greening the Automotive Workforce (2011).

[49] Dziczek and others, "Driving Workforce Change"; McAlinden, Dziczek, and others, "Beyond the Big Leave."

[50] Data on job openings are from the Conference Board's Help Wanted OnLine (HWOL) data series, including all online advertised job vacancies, which are accumulated from a large number of online job boards before removing duplicate announcements. Data on the educational requirements of auto-specialized occupations are from a Brookings review of two Department of Labor sources regarding education and training requirements: the Occupational Information Network (O*NET) developed by the Employment and Training Administration and the education and training classification system developed by the Bureau of Labor Statistics.

[51] While online job postings are subject to selection bias in that online ads are not equally used by all employers or for all occupations, data on advertised job openings are nonetheless one of the most direct methods available to assess employer demand. Meanwhile, some biases of the data are known and pertain to this discussion. Notably, a comparison of online job postings from the Conference Board's HWOL data series to employment counts from the BLS Occupational Employment Survey at the two-digit Standard Occupational Classification (SOC) code for the state of Tennessee found that professional occupations were overrepresented and production occupations were underrepresented in HWOL compared to the Tennessee employment base. Anecdotal information suggests that manufacturers use different recruiting methods for different occupational groups, with production workers more likely to be hired by word-of-mouth, signs, and referrals than professional workers. Thus, it is likely that the HWOL-based measures underrepresent demand for production workers and, given this sampling bias, measures of "hardness-to-fill" between occupational clusters are not perfectly comparable.

[52] Brookings analysis of IPUMS data, using the geography of the Census-designated Southern region of the United States.

[53] Paul Osterman and Diane M. Burton, "Ports and Ladders: The Nature and Relevance of Internal Labor Markets in a Changing World," in Pamela Tolbert and Rosemary Batt, eds., *Oxford Handbook on Work and Organization* (Oxford: Oxford University Press, 2004); Carolyn J. Heinrich, Peter R. Mueser, and Kenneth R. Troske, "The Role of Temporary Help Employment in Low-Wage Worker Advancement," Working Paper 13520 (Washington: National Bureau of Economic Research, 2007); Garth Mangum, Donald Mayall, and Kristin Nelson, "The Temporary Help Industry: A Response to the Dual Internal Labor Market," *Industrial and Labor Relations Review* 38 (4) (1985): 599-611.

[54] Interviews with employers, June 12, 2013.

[55] Brookings analysis of the National Center for Education Statistics Integrated Postsecondary Education Data System.

[56] Private postsecondary institutions, both nonprofit and for-profit, also offer programs that feed into auto-specialized occupations. For-profit two-year institutions awarded almost 1,700 postsecondary awards in 2011 in fields of study leading to auto-specialized occupations, the vast majority of them in automotive mechanics. For-profit four-year colleges and universities awarded 785 degrees leading to auto-specialized occupations, three-quarters of them in business-related fields. Nonprofit two-year schools awarded almost 50 degrees, in a mix of production and business-related fields of study. Nonprofit four-year colleges and universities awarded almost 3,000 degrees leading to auto-specialized occupations, in a mix of engineering and business-related fields of study.

[57] The Motlow mechatronics program includes a 16-credit-hour course of study for the Siemens Level I Assistant Machine Operator certificate as well as a two-year associate of science degree and preparation for the Associate Technician and Professional Designer designation exams. "Bridgestone and Motlow College Mechatronics Partnership," available at www.mscc.edu/bridgestone (August 2013). The Volkswagen Academy offers three-year degree programs in automation mechatronics and car mechatronics. Both programs include paid internships at the Volkswagen plant. "Volkswagen Academy In Partnership with Chattanooga State," available at www.chattanoogastate.edu/engineering-technology/partnerships/vw-academy (August 2013).

[58] Sam Stockard, "Legislators Say 2013 Session Productive," (Murfreesboro, TN) *Daily News Journal*, May 15, 2013; G. Chambers Williams, "$50 Million High-Tech Training Center Set for Smyrna," *The Tennessean*, June 10, 2013; "Tennessee Tech Center Kicks Nissan to Next Gear," (Murfreesboro, TN) *Daily News Journal*, June 8, 2013; Sam Stockard, "Nissan Plans to Break New Ground," (Murfreesboro, TN) *Daily News Journal*, June 5, 2013.

[59] Employer interview, May 14, 2013.

[60] Interviews with employers, June 12, 2013.

[61] In addition to employers, partners include the Tennessee Board of Regents, leadership of area community colleges and TCATs, economic development officials, workforce boards, and chambers of commerce.

[62] "Program Overview," available at www.manufacturingfuture.net/programs.php (July 2013).

[63] Interview with Dean Wayne Davis, April 2013.

[64] "Tennessee Governor's Chairs," available at www.utk.edu/govchairs (April 2013).

[65] "Growing Quality Jobs in Tennessee" (New York: Battelle Technology Partnership Practice, 2011).

[66] Ibid.

[67] Based on internal data provided by the University of Tennessee, 2013.

[68] "Center for Technology Transfer—Vanderbilt University," available at www.vanderbilt.edu/cttc/technologies/research-tools (April 2013).

[69] "National Science Foundation Statistics," available at www.nsf.gov/statistics (April 2013).

[70] National Science Foundation, Science and Engineer Statistics, 2008.

[71] Center for Automotive Research, "Contribution of the Automotive Industry to the Economies of All Fifty States and the United States" (Ann Arbor: 2010).

[72] Phone interview with Battelle researcher Anthony Gillespie, April 15, 2013. See also Stephen Ezell, "International Benchmarking of Countries' Policies and Programs Supporting SME Manufacturers" (Washington: Information Technology & Innovation Foundation, 2011).

[73] Of the 26 R&D Magazine Awards won by Oak Ridge between 2009 and 2011, more than one-third were in technologies or processes relevant to the automotive industry (material sciences, mechanical and process innovations). *R&D Magazine* R&D Awards, available at www.rdmag.com/articles/2009/07/r-d-100-awards (May 2013).

[74] "Bridging the Gap 2013," available at http://www.ornl.gov/connect-with-ornl/for-industry/partnerships/events-and-conferences/bridging-the-gap-2013 (September 2013).

[75] The Carbon Fiber Consortium run through Oak Ridge National Laboratory is an important counterexample and potential forum for important technology and business strategy sharing. Currently the consortium includes 45 member companies. Though the majority of these firms are international, close to one-third have operations in Tennessee. See "Oak Ridge Carbon Fiber Composites Consortium," available at www.cfcomposites.org/ (June 2013).

[76] Matthew Stepp and others, "Turning the Page: Reimagining the National Labs in the 21st Century Innovation Economy" (Washington: Information Technology & Innovation Foundation, Center for American Progress, and Heritage Foundation, 2013).

[77] Phone interview with Jeff McCay, April 7, 2013.

[78] In 2012, LaunchTN's Technology Maturation Fund supported $400,000 to eight research organizations, entrepreneurs, or investors in clean energy, life sciences, and information technology industries. Another funding program run through LaunchTN, the INCITE Co-Investment Fund, provides venture capital to small technology firms in Tennessee. The fund is backed by a $29.7 million award through the U.S. Department of Treasury's State Small Business Credit Initiative. To date only one auto firm has won INCITE funding: Cyber Physical Systems, Inc., which is developing an automatic crash notification system. See "LaunchTN Press Releases," available at http://launchtn.org/newsroom/press-releases/press-release-august-incite (June 2013).

[79] "autoXLR8R- About Us," available at www.smtec.com/autoxlr8r/about (June 2013).

CHAPTER VI

[1] To calculate supply chain density, the number of jobs in the supply chain was divided by the number of employees in the state's OEMs. Labor productivity is based on Brookings analysis of data from the Bureau of Labor Statistics, Output per Hour and Moody's Analytics. Auto R&D per worker and patents are based on Brookings analysis of Harvard's Cluster Mapping Project.

CHAPTER VIII

[1] See, for example, Michael Porter, "Clusters and Economic Policy: Aligning Public Policy With the New Economics of Competition," White Paper (Cambridge: Institute for Strategy and Competitiveness, 2009).

[2] Karen Mills, Elisabeth Reynolds, and Andrew Reamer, "Clusters and Competitiveness: A New Federal Role for Stimulating Regional Economies" (Washington: Brookings Institution, 2008).

[3] For further information on the importance of work-based learning, see McAlinden, Dziczek, and others, "Beyond the Big Leave"; Robert Halpern, *The Means to Grow Up: Reinventing Apprenticeship as a Developmental Support in Adolescence* (New York: Routledge, 2009); Nancy Hoffman, *Schooling in the Workplace: How Six of the World's Best Vocational Education Systems Prepare Young People for Jobs and Life* (Boston: Harvard Educational Publishing Group, 2011); and Organization for Economic Cooperation and Development, "Learning for Jobs" (Paris: 2010).

[4] Stephen Ezell, "Lessons From Foreign Countries on How U.S. States Can Spur Manufacturing." *InnovationFiles*, April 9, 2012.

[5] For more information on the New Mexico Small Business Assistance program, see www.nmsbaprogram.org (September 2013).

[6] Rob Atkinson, "Effective Corporate Tax Reform in the Global Innovation Economy" (Washington: Information Technology & Innovation Foundation, 2009).

[7] Ibid.

[8] Mark Muro, "Strengthening U.S. Manufacturing, Region by Region," *The Avenue,* May 13, 2013.

[9] Amy Liu, Brad McDearman, and Marek Gootman, "Strengthen Federalism: Establish a Regional Export Accelerator Challenge (REACH) Grant Program to Boost U.S. Export and Trade Capacity" (Washington: Brookings Institution, 2013).

[10] The Workforce Investment Act, the Carl D. Perkins Career and Technical Education Act, the Elementary and Secondary Education Act, and the Higher Education Act should all be considered jointly rather than in isolation.

[11] Bruce Katz and Peter Hamp, "Cut to Invest: Create a 'Race to the Shop' Competition for Advanced Manufacturing" (Washington: Brookings Institution, 2013).

[12] Office of Management and Budget, "Budget of the United States Government, Fiscal Year 2014" (Washington: Executive Office of the President), 82.

[13] President's Council of Advisors on Science and Technology, "Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future" (Washington: Executive Office of the President, 2010), 102.

[14] President's Council of Advisors on Science and Technology, "Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing" (Washington: Executive Office of the President, 2012).

[15] President's Council of Advisors on Science and Technology, "National Network for Manufacturing Innovation: A Preliminary Design" (Washington: Executive Office of the President, 2013); and National Academy of Engineering, "Engineering Research and America's Future: Meeting the Challenges of a Global Economy" (Washington: National Academies, 2005).

[16] Ezell and Atkinson, "International Benchmarking of Countries' Policies and Programs."

[17] Jessica Lee and Mark Muro, "Make the Research & Experimentation Tax Credit Permanent" (Washington: Brookings Institution, 2013). See also Atkinson, "Effective Corporate Tax Reform in the Global Innovation Economy."

APPENDIX E

[1] "And the Winners Are...: Accomplishments of Distinction at Oak Ridge National Laboratory," *Oak Ridge National Laboratory Review,* available at www.ornl.gov/info/ornlreview/v39_3_06/article25.shtml (September 2013).

[2] "The University of Tennessee Cherokee Farm Campus: Development Guidelines," available at http://bot.tennessee.edu/docs/Cherokee_Farm_Campus.pdf (September 2013).

[3] Center for Technology Transfer and Commercialization at Vanderbilt University, "20 Years of Innovation 1991-2011," available at http://cttc.co/cttc/news/anniversary-report-20-years-innovation (September 2013).

[4] "Center for Technology Transfer & Commercialization," available at www.vanderbilt.edu/cttc (September 2013).

SELECTED REFERENCES

General

Atkinson, Robert. 2012. "Innovation in Cities and Innovation by Cities." Washington: Information Technology & Innovation Foundation.

Atkinson, Robert, and Stephen Ezell. 2013. *Innovation Economics: The Race for Global Advantage.* New Haven: Yale University Press.

Audretsch, David, and Maryann Feldman. 2004. "Knowledge Spillovers and the Geography of Innovation." In J. Vernon Henderson and Jean-Francois Thisse, eds., *Handbook of Urban and Regional Economics, Volume 4: Cities and Geography.* Amsterdam: Elsevier.

Berube, Alan. 2007. "MetroNation: How U.S. Metropolitan Areas Fuel American Prosperity." Washington: Brookings Institution.

Katz, Bruce. 2010. "City Centered: Investing in Metropolitan Areas to Build the Next Economy." *TIME Magazine*. November 1.

——. 2010. "Delivering the Next American Economy: From Macro Vision to Metro Action." Speech at the Global Metro Summit. December 8. Chicago.

Katz, Bruce, and Jennifer Bradley. 2013. *"The Metropolitan Revolution: How Cities and Metros are Fixing Our Broken Politics and Fragile Economy*. Washington: Brookings Institution.

Katz, Bruce, and Mark Muro. 2012. "Remaking Federalism | Renewing the Economy: Resetting Federal Policy to Recharge the Economy, Stabilize the Budget, and Unleash State and Metropolitan Innovation." Washington: Brookings Institution.

Katz, Bruce, Jennifer Bradley, and Amy Liu. 2010. "Delivering the Next Economy: The States Step Up." Washington: Brookings Institution.

McKinsey Global Institute. 2011. "Growth and Renewal in the United States: Retooling America's Economic Engine."

Muro, Mark, and Bruce Katz. 2010. "The New 'Cluster Moment:' How Regional Innovation Clusters Can Foster the Next Economy." Washington: Brookings Institution.

Muro, Mark, and others. 2008. "MetroPolicy: Shaping a New Federal Partnership for a Metropolitan Nation." Washington: Brookings Institution.

National Governors Association. 2012. "Redesigning State Economic Development Agencies." Washington.

Powell, Walter and Stine Grodal. 2005. "Networks of Innovators." In Jan Fagerberg, David C. Mowery, and Richard R. Nelson, eds., *The Oxford Handbook of Innovation.* London: Oxford University Press.

Advanced Industries

Berger, Suzanne. 2013. *Making in America: From Innovation to Market*. Cambridge: MIT Press.

Bonvillian, William. 2012. "Reinventing American Manufacturing: The Role of Innovation." *Innovations* 7 (3): 97–125.

Carey, David, Christopher Hill, and Brian Kahin. 2012. "Strengthening Innovation in the United States." Economics Department Working Paper 1001. Paris: Organization for Economic Cooperation and Development.

DeWeck, Olivier, and others. 2013. "Trends in Advanced Manufacturing Technology Innovation." Draft chapter. Cambridge: Massachusetts Institute of Technology.

Ezell, Stephen, and Robert Atkinson. 2011. "The Case for a National Manufacturing Strategy." Washington: Information Technology & Innovation Foundation.

——. 2011. "International Benchmarking of Countries' Policies and Programs Supporting SME Manufacturers." Washington: Information Technology & Innovation Foundation.

Hart, David. 2012. "The Future of Manufacturing: The United States Stirs." *Innovations* 7 (3): 19–28.

Hart, David, and others. 2012. "Why America Needs a National Network for Manufacturing Innovation." Washington: Information Technology & Innovation Foundation.

Helper, Susan, Timothy Krueger, and Howard Wial. 2012. "Why Does Manufacturing Matter? Which Manufacturing Matters? A Policy Framework." Washington: Brookings Institution.

Locke, Richard, and Rachel Wellhausen, eds. 2013. *Production in the Innovation Economy.* Cambridge: MIT Press.

Manyika, James, Daniel Pacthod, and Michael Park. 2011. "Translating Innovation into U.S. Growth: An Advanced-Industries Perspective." *McKinsey Quarterly*. May.

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

——. 2013. "Disruptive Technologies: Advances that Will Transform Life, Business, and the Global Economy." McKinsey Global Institute.

Massachusetts Institute of Technology. 2013. "A Preview of the MIT Production in the Innovation Economy Report." MIT Press.

McKinsey & Co. 2011. "Accelerating Growth and Innovation in the U.S. Advanced Industries (AI) Sector." PowerPoint. New York.

McKinsey Global Institute. 2013. "Resource Revolution: Tracking Global Commodity Markets." September.

Morrison, Tom, Emily DeRocco, and others. 2011. "Boiling Point? The Skills Gap in U.S. Manufacturing." Deloitte and the Manufacturing Institute.

Muro, Mark. 2013. "Catalyzing Manufacturing Competitiveness with Targeted Responses to Key Market Failures." Statement before the Subcommittee on Research and Technology, Committee on Science, Space, and Technology. U.S. House of Representatives. 112th Congress.

Muro, Mark, and Kenan Fikri. 2013. "Manufacturing Hubs: What and Why." *Up Front.* A blog of the Brookings Institution. February 13.

Muro, Mark, and Jessica Lee. 2012. "Hubs of Manufacturing: Let's Get Started." *Up Front.* A blog of the Brookings Institution. August 20.

Muro, Mark, and others. 2013. "Launch! Taking Colorado's Space Economy to the Next Level." Washington: Brookings Institution.

Pacthod, Daniel, and Michael Park. 2012. "How Can the U.S. Advanced Industries Sector Maintain its Competitiveness?" New York: McKinsey & Co.

Pisano, Gary, and Willy Shih. 2012. *Producing Prosperity: Why American Needs a Manufacturing Renaissance.* Boston: Harvard Business Review Press.

Shipp, Stephanie, and others. 2012. "Emerging Global Trends in Advanced Manufacturing." Alexandria, VA: Institute for Defense Analysis.

Sirkin, Harold, and others. 2011. "Made in America, Again: Why Manufacturing Will Return to the U.S." Boston: Boston Consulting Group.

Sirkin, Harold, and others. 2013. "Behind the American Export Surge: The U.S. as One of the Developed World's Lowest-Cost Manufacturers." Boston: Boston Consulting Group.

Sperling, Gene. 2012. Remarks at the Conference on the Renaissance of American Manufacturing. March 27.

——. 2013. "The Case for a Manufacturing Renaissance." Remarks at the Brookings Institution. July 25.

Waldman, Cliff, and Matthew Murray. 2013. "Advanced Manufacturing in the American South: An Economic Analysis Supporting Regional Development." Washington: Manufacturers Alliance for Productivity and Innovation.

Auto Economy

Helper, Susan. 2013. "Interpreting Recent Trends in the U.S. Auto Industry." Washington: U.S. Department of Commerce, Office of the Chief Economist. July 9.

Helper, Susan, and others. 2011. "The U.S. Auto Supply Chain at a Crossroads: Implications of an Industry in Transformation." Cleveland: Case Western Reserve University.

Hill, Kim, and Emilio Brahmst. 2003. "The Auto Industry Moving South: An Examination of Trends." Ann Arbor: Center for Auto Research.

International Trade Administration. 2007. "The American Automotive Industry Supply Chain—In the Throes of a Rattling Revolution." U.S. Department of Commerce.

——. 2011. "On the Road: U.S. Automotive Parts Industry Annual Assessment." Washington: U.S. Department of Commerce.

——. 2013. "Trends in U.S. Vehicle Exports." Washington: U.S. Department of Commerce, Office of Transportation and Machinery. July.

Jacobs, A.J. 2012. "Collaborative Regionalism and Foreign Direct Investment: The Case of the Southeast Automotive Core and the 'New Domestics.'" *Economic Development Quarterly* 26 (3): 199–219.

Klier, Thomas, Paul Ma, and Daniel McMillen. 2004. "Comparing Location Decisions of Domestic and Foreign Auto Supplier Plants." Working Paper 2004-27. Chicago: Federal Reserve Bank of Chicago.

Klier, Thomas, and James Rubenstein. 2008. *Who Really Made Your Car? Restructuring and Geographic Change in the Auto industry.* Kalamazoo, MI: W.E. Upjohn Institute for Employment Research.

Klier, Thomas, and Daniel McMillen. 2008. "Evolving Agglomeration in the U.S. Auto Supplier Industry." *Journal of Regional Science* 48 (1): 245–267.

Maurer, Andreas, Frank Dietz, and Nikolaus Lang. 2003. "Rethinking Automotive Purchasing: From Price Pressure to Partnership." Boston Consulting Group.

McKinsey & Co. 2011. "Global Megatrends and their Impact on the Automotive Sector." PowerPoint Presentation. New York.

——. 2012. "Mobility of the Future: Opportunities for Automotive OEMs." New York.

——. 2012. "The Future of the North American Automotive Supplier Industry: Evolution of Component Costs, Penetration, and Value Creation Potential Through 2020." New York.

Miroff, Nick. 2013. "With Mexican Auto Manufacturing Boom, New Worries." *Washington Post*. July 1.

Rogers, Christina and Neal Boudette. 2013. "A Revitalized Car Industry Cranks Up U.S. Exports." *Wall Street Journal*. July 1.

Rosen, Jeffrey and Kimberly DuBord. 2012. "State of U.S. Motor Vehicle Industry: 2012." Chicago: Briefing.com, Inc.

Sturgeon, Tim. 2002. "Modular Production Networks: A New American Model of Industrial Organization." *Industrial and Corporate Change* 11 (3): 451-496.

——. 2008. "Value Chains, Networks, and Clusters: Reframing the Global Automotive Industry." *Journal of Economic Geography* 8: 2097-2321.

Thomas, Kelly. 2012. "The Automotive Supply Chain in the New Normal: Analysis of the Industry and its Supply Chain Opportunities—Ideas for Driving $1 Billion in Operating Margin." Scottsdale: JDA Software Group, Inc.

Tennessee

Battelle Technology Partnership Practice. 2011. "Growing Quality Jobs in Tennessee: A White Paper on Leveraging Tennessee's Research and Development Base for Innovation and Technology Commercialization." Prepared for Tennessee Technology Development Corp. Washington.

Fox, William, and William Hamblen. 2013. "Economic Impact of the Volkswagen Assembly Plant in 2012." Knoxville: Center for Business & Education Research.

LaunchTN. 2012. "Annual Report to Governor and General Assembly." Nashville.

——. 2013. "Entrepreneurship and Innovation in Tennessee 2012." Nashville.

Ochs Center for Metropolitan Studies. 2013. "State of Chattanooga Region Report: Education." Chattanooga.

Reynolds, Melissa, and Matthew Murray. 2012. "A Profile of the Automobile Industry in Tennessee." Knoxville: University of Tennessee Center for Business and Economic Research.

Tennessee Department of Economic and Community Development. 2011. "Jobs4TN Plan." PowerPoint Presentation. Nashville.

——. 2013. "International Division Strategy." Nasvhille.

University of Tennessee Center for Business and Economic Research and Department of Agricultural Economics. 2013. "An Economic Report to the Governor of the State of Tennessee." Knoxville.

Workforce Investment Network. 2013. "Made in Memphis: Manufacturing Industry Survey Report and Recommendations." Memphis.

Policy

Ezell, Stephen, and Robert Atkinson. 2012. "Fifty Ways to Leave Your Competitiveness Woes Behind: A National Traded Sector Strategy." Washington: Information Technology & Innovation Foundation.

Katz, Bruce, and Peter Hamp. 2013. "Cut to Invest: Create a 'Race to the Shop' Competition for Advanced Manufacturing." Washington: Brookings Institution.

Lee, Jessica, and Mark Muro. 2012. "Cut to Invest: Make the Research and Experimentation Tax Credit Permanent." Washington: Brookings Institution.

Muro, Mark, and Kenan Fikri. 2011. "Job Creation on a Budget: How Regional Industry Clusters Can Add Jobs, Bolster Entrepreneurship, and Spark Innovation." Washington: Brookings Institution.

National Center for Higher Education Management Systems. 2011. "Performance Funding: From Idea to Action." Washington: Complete College America.

National Governors Association. 2013. "'Making' Our Future: What States Are Doing to Encourage Growth in Manufacturing through Innovation, Entrepreneurship, and Investment." Washington.

——. 2013. "Top Trends in State Economic Development." Washington.

OECD. 2013. "Raising the Returns to innovation: Structural Policies for a Knowledge-Based Economy." *OECD Economics Department Policy Notes,* No. 17.

President's Council of Advisors on Science and Technology. 2011. "Report to the President on Ensuring American Leadership in Advanced Manufacturing." Washington: Executive Office of the President.

——. 2012. "Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing." Washington: Executive Office of the President.

——. 2012. "Transformation and Opportunity: The Future of the U.S. Research Enterprise." Washington: Executive Office of the President.

Saha, Devashree, and Mark Muro. 2013. "Cut to Invest: Create a Nationwide Network of Advanced Industries Innovation Hubs." Washington: Brookings Institution.

Stepp, Matthew, and others. 2013. "Turning the Page: Reimagining the National Labs in the 21st Century Innovation Economy." Washington: Information Technology & Innovation Foundation, Center for American Progress, and Heritage Foundation.

Turner, Mark, and others. 2013. "Evaluation of the U.S. Small Business Administration's Regional Clusters Initiative: Two Year Report." Washington: U.S. Small Business Administration.

U.S. Congress Joint Economic Committee. 2012. "STEM Education: Preparing for the Jobs of the Future." Washington.

Workforce Development

Dziczek, Kristin, and others. 2011. "Driving Workforce Change: Regional Impact and Implications of Auto Industry Transformation to a Green Economy." The Driving Change Project.

McAlinden, Sean, Kristin Dziczek, and others. 2008. "Beyond the Big Leave: The Future of U.S. Automotive Human Resources." Ann Arbor: Center for Automotive Research.

National Governor's Association, Corporation for a Skilled Workforce, and National Skills Coalition. 2013. "State Sector Strategies Coming of Age: Implications for State Workforce Policymakers."

ACKNOWLEDGMENTS

Authors accrue many debts in a project like this and this one is no exception. To start with, the project team is especially grateful to Gov. Bill Haslam for welcoming its work and to Will Alexander, Randy Boyd, Charlie Brock, and Mark Cate in the Haslam administration for supporting the project.

Meanwhile, Thomas Brewer and Bill May served as superb guides to the Tennessee automotive industry.

More broadly, the authors would like to thank the following Tennesseans for their varied and important contributions to this work: Billy Lee Adams Jr., Sen. Lamar Alexander, Mary Lou Apple, Stephen Arnette, Scott Becker, Craig Blue, Emily Boylan, Mike Bradshaw, James Catanzaro, Debbie Clabo, Tim Connearney, Tom Croskey, Linda Davis, Wayne Davis, Russ Deaton, Rupa DeLoach, Emily DeRocco, Reid Dulberger, Taylor Eighmy, Nancy Eisenbrandt, David Elrod, Enoch Elwell, Jennifer Evans, Ralph Gwaltney, Keith Hamilton, Ginger Hausser, Paul Haynes, Patsy Hazelwood, Kevin Hedges, Sue Helper, Eric Henning, Jim Hollingshead, Dan Holton, Paul Jennings, Dennis Jones, Greg Jones, Motohiko Kato, Bill Kreuger, James King, Ju-Hsin Lusk, Dan Marcum, Thom Mason, Jeff McCord, Jan McKeel, Danielle Mezera, Steven Moore, Matt Murray, Warren Nichols, Sen. Mark Norris, Stacey Patterson, Carol Puryear, Rhonda Rice, Richard Rhoda, Marc Robinson, Tom Rogers, Alice Rolli, Ralph Schulz, Lori Shauntee, Penny Shelton, Tim Shelton, Timothy Slattery, Scott Sloan, Brad Smith, Jesse Smith, Ron Smithfield, Pamela Stamps, Glenn Stevens, Brian Sullivan, Frankie Swafford, Angela Talley, John Townsend, Ted Townsend, Jill Van Beke, Sterling van der Spuy, David Washburn, Charles Wesenberg, Charles Wood, and David Wright.

The Brookings team would also like to thank McKinsey & Co. for contributing important insights about dynamics within the global automotive supply chain.

Closer to home sincere thanks go to: Alan Berube, Tsvetlin Bikov, Peter Blankenship, Junwei Chen, Franklin Chou, Nathan Einstein, Rachel Harvey, Celine Hu, David Jackson, Rachel Jaffe, Bruce Katz, Sid Kulkarni, Amy Liu, Brad McDearman, Ellen Ochs, Joe Parilla, Benjamin Robinson, Maria Sese-Paul, Richard Shearer, Phoebe Silag, Karen Slachetka, Ben Slowik, Taylor Stewart, Owen Washburn, and Howard Wial.

The Metropolitan Policy Program at Brookings would like to thank the Rockefeller Foundation for its support of the Brookings-Rockefeller Project on State and Metropolitan Innovation, which presents fiscally responsible ideas state and metropolitan leaders can use to create an economy that is driven by exports, powered by low carbon, fueled by innovation, rich with opportunity and led by metropolitan areas.

The Program would also like to thank the Alcoa Foundation and the GE Foundation for their support of this work as well as the John D. and Catherine T. MacArthur Foundation, the Heinz Endowments, the George Gund Foundation, the Kresge Foundation, and the Surdna Foundation for their general support of the program's research and policy efforts. We would also like to thank the Metropolitan Leadership Council, a network of individual, corporate, and philanthropic investors that provide us financial support but, more importantly, are true intellectual and strategic partners.

ABOUT THE AUTHORS

Mark Muro is a senior fellow and policy director at the Brookings Metropolitan Policy Program. He leads the Metro Program's advanced industries activities. Scott Andes is a senior policy analyst, Kenan Fikri is a research analyst, Martha Ross is a fellow, Jessica Lee is a senior policy analyst and associate fellow, Neil Ruiz is a senior policy analyst and associate fellow, and Nick Marchio is a research assistant at the program.

ADVANCED INDUSTRIES SERIES

This paper is part of the Brookings Metropolitan Policy Program's Advanced Industries series. This series calls attention to the critical role that advanced industries—characterized by STEM-worker- and R&D-intensive industrial concerns—play in building and sustaining regional and national economic competitiveness. By working intensively with two emblematic state AI clusters to develop actionable economic development strategies to advance the clusters the series seeks to highlight the value of AIs to national policymakers and so further regional and national prosperity in the United States. Early in 2014 a national framing paper will build on the state analyses to assert the long-term importance of AIs—and federal, state, and regional action to foster them.

IN THE SERIES

- *Launch! Taking Colorado's Space Economy to the Next Level*
- *Drive! Moving Tennessee's Automotive Sector Up the Value Chain*

ABOUT THE METROPOLITAN POLICY PROGRAM AT THE BROOKINGS INSTITUTION

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 GENERAL INFORMATION

Metropolitan Policy Program at Brookings
202.797.6139
www.brookings.edu/metro

1775 Massachusetts Avenue NW
Washington, D.C. 20036-2188
telephone 202.797.6139
fax 202.797.2965

BROOKINGS

Metropolitan Policy Program at BROOKINGS