Promoting Advanced Manufacturing Clusters in Tennessee[1]

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Introduction

The University of Tennessee's Center for Industrial Service (CIS) has a vision for a Tennessee manufacturing industry that is characterized by innovative and prosperous businesses, high-quality jobs, and a safe and healthy workplace. CIS seeks to identify and facilitate growth among advanced manufacturing industries in order to promote the economic well-being and fiscal health of Tennessee. Fostering economic growth requires a high-quality business environment that encourages innovation and rising productivity (Porter, 2001). Consequently, a focus on the development of advanced manufacturing, which is characterized by a higher educated workforce and higher rates of process innovation, may be one of the more direct routes towards further growth and prosperity.

Advanced manufacturing firms may also yield spillover benefits to the state. For example, the presence of advanced manufacturing firms can send important signals regarding the strength and vitality of the state's economy. In addition, advanced manufacturing enterprises can attract a larger pool of high-skilled workers and raise expectations for in-state workers and educators. Tennessee has consistently lagged behind the nation in educational attainment rates, average earnings and household income, all of which are strong indicators of regional demand and economic development. Creating new jobs in advanced manufacturing fields may provide incentives for higher educated workers to relocate to Tennessee and more importantly give stronger incentives to Tennessee residents to seek further education and training.

In practice, conceptual definitions associated with advanced manufacturing, along with practical data constraints, make it exceedingly difficult to identify advanced manufacturing industries and firms. This chapter uses a process-oriented definition of advanced manufacturing that allows for indirect identification of firms and industries based on the earnings that accrue to workers. More productive workers generally receive higher wages and are often employed in more advanced production processes, so this approach has considerable intuitive appeal. A regional (i.e. statewide) cluster-based approach is also used in the identification of advanced manufacturing industries.

The cluster approach yields four candidate sets of industries that warrant consideration for policy support and technical assistance. The first, the high-wage cluster, is the one that is most closely related to the notion of advanced manufacturing by virtue of the very high earnings that accrue to workers. Also identified is a well-established cluster of firms and industries that pay relatively high wages and account for a large share of employment in the state. A high-potential and an aspirational cluster are also examined. The high-potential cluster is characterized by high earnings but a very small share of national employment. The large national employment level may offer the potential for the transferal of jobs to Tennessee. The aspirational cluster includes firms that pay relatively low wages and could benefit from productivity-enhancing business practices. This cluster is not indicative of advanced manufacturing. But given the strong presence in the state, the application of advanced manufacturing practices may enhance productivity and competitiveness.

The remainder of the chapter is organized as follows. The discussion immediately below frames the state of the manufacturing sector in Tennessee. Next is a discussion of the nature of advanced manufacturing followed by a presentation of core concepts of cluster analysis. Subsequent sections provide data and commentary on the nature of the four sets of clusters.

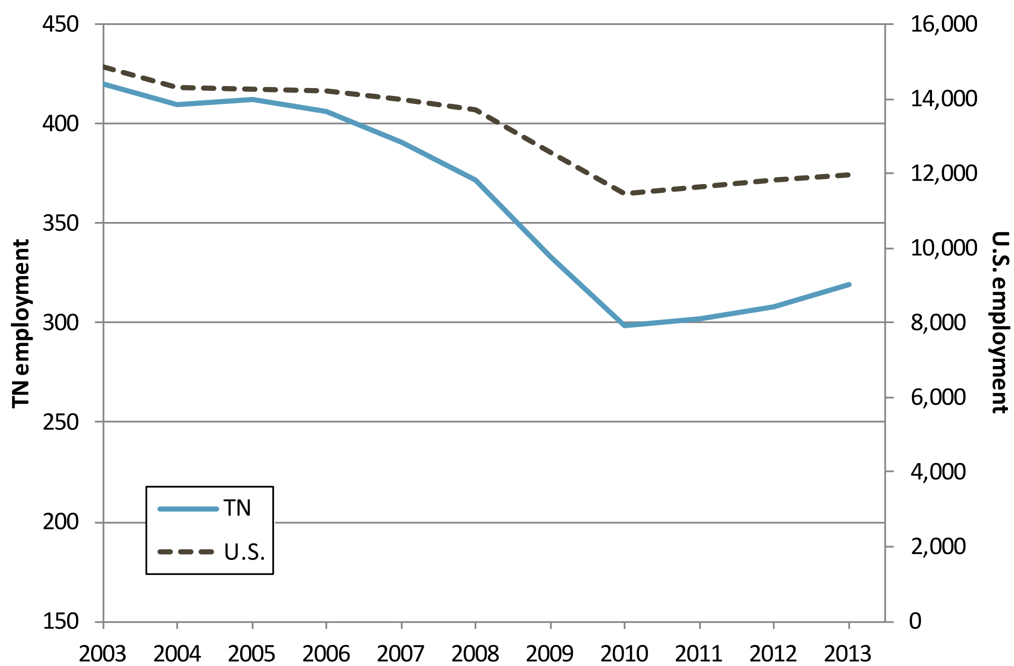
Context: Trends in Tennessee Manufacturing

Over the last decade the number of manufacturing jobs in Tennessee and in the U.S. has declined sharply. The Great Recession hit the manufacturing industry noticeably hard. From 2007 to 2010 over 2.7 million manufacturing jobs were lost in the U.S., 100,000 of which came from Tennessee. Manufacturing employment has slowly begun to bounce back (in both Tennessee and the U.S.) but is nowhere near pre-recession levels (Figure 1). Unfortunately, while job growth in manufacturing is expected to continue for the next several years, the gains will not erase the losses that have transpired since 2007. Before the end of the decade, manufacturing will once again experience employment losses. A primary explanation is the expectation that manufacturing output levels will have been restored well above prerecession levels of production. Once the manufacturing sector returns to something akin to full employment, trend contraction will again set in.

Manufacturing has long played a vital role in the Tennessee economy. By 2003, manufacturing employment represented 14.6 percent of total nonfarm employment in the state (compared to 10.5 percent in the country.) However, Figure 2 shows that manufacturing's employment share has been on the downswing ever since. In fact, manufacturing employment approached one-third of all jobs in the state in the 1960s and 1970s so the trend shown in Figure 1 understates the long-term losses for the state.

Despite these bleak employment figures, manufacturing output has expanded in recent years, and is nearing pre-recession levels as shown in Figure 3. Figures 1 and 3 together indicate significant gains in manufacturing productivity, i.e. output per worker, as fewer and fewer workers have been able to produce more and more output. This has largely been driven by rapid technological progress during the late-20th and early-21st century along with industry requirements for better skilled workers—industry technology and the need for skilled workers go hand-in-hand. Advancements in computer technology, for example, have made product development, shipping, and inventory management easier and more efficient, while the emergence and expansion of the internet has made communication between buyers and sellers easier and more reliable. These developments

Figure 1: U.S. and Tennessee Manufacturing Employment Enjoys Short-Term Rebound (in thousands)



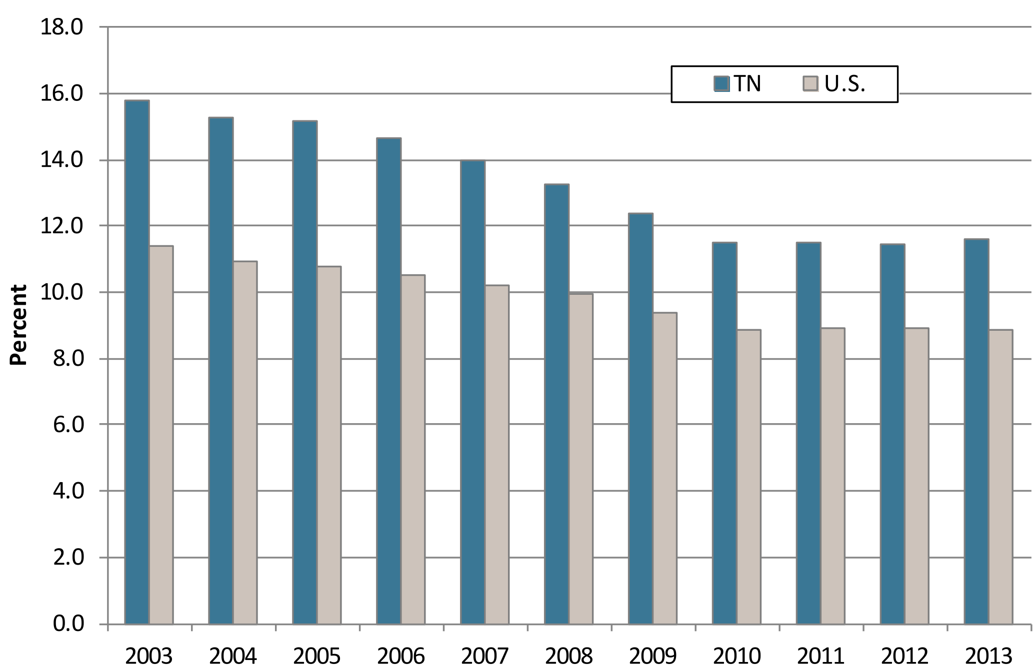
Source: Bureau of Economic Analysis.

have streamlined the manufacturing process from start to finish, resulting in reduced production costs and increased productivity.

Historically Tennessee's industrial labor pool was both abundant and unskilled. That has changed markedly in recent years as the industry has increasingly shifted its demand to highly-skilled workers. Technological advancements have also helped create a more globalized economy which has given manufacturing firms the opportunity to extend business into overseas markets. This same globalization has also led to greater foreign competition both in domestic and international markets. Countries such as Brazil, China, India, and Russia, for example, have all become stronger economic forces in the global marketplace and represent additional competition for firms in the U.S. and in Tennessee.

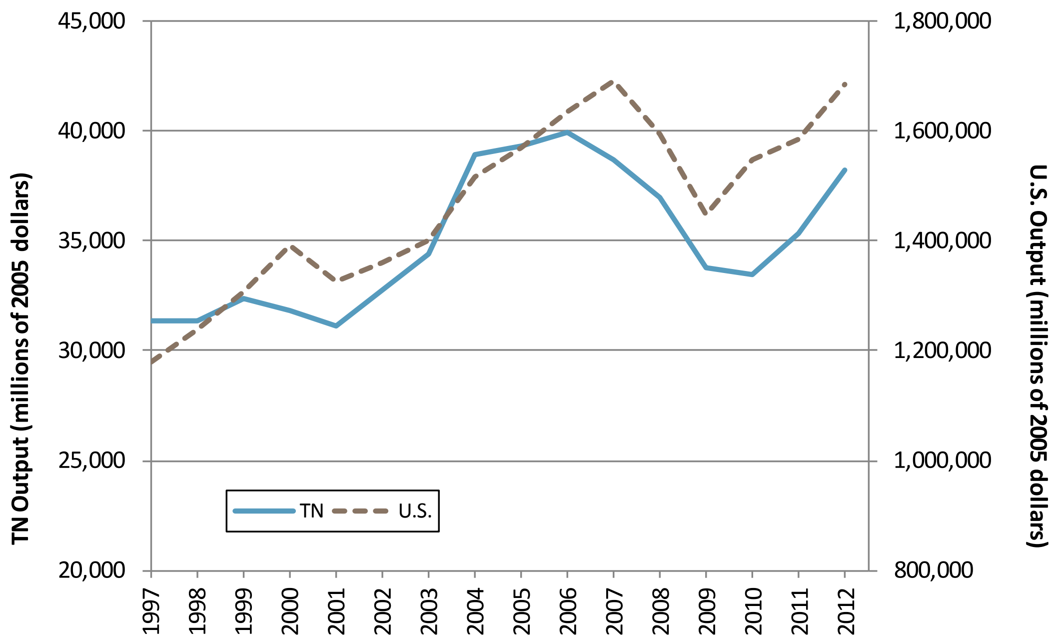
In years past, lower input prices (such as lower wages and lower costs for land) were, to some degree, viewed as an asset for southern states such as Tennessee, as it helped lure cost-minimizing firms into relocating within the state's borders. However, with globalization, firms have found even cheaper labor overseas (in countries such as China), and states such as Tennessee will need to find new ways to compete. This should be viewed as an opportunity for Tennessee to continue to transform its workforce from a low-cost labor force to one of high quality and higher skills. While low wages may have helped attract some new firms into the state they have also been a burden to the Tennessee economy by keeping consumer income low and dampening regional demand. Focusing on increasing the skill level of the region's workforce through advanced education and training could greatly benefit the region's economy by increasing productivity and putting upward pressure on employee wages.

Figure 2: Manufacturing Employment as Share of Total Nonfarm Employment Trends Downward



Source: Bureau of Labor Statistics.

Figure 3: U.S. and Tennessee Manufacturing Output Trend Upward



Source: U.S. Bureau of Economic Analysis.

Advanced Manufacturing

Advanced manufacturing represents one important component of the state's overall manufacturing sector. However, a number of difficulties immediately arise when attempting to identify advanced manufacturing industries for developmental consideration. First, is the burden of defining what exactly constitutes advanced manufacturing. As noted in Waldman and Murray (2013), it is difficult to find a fully accepted definition of advanced manufacturing because the term "advanced" is, by nature, both relative and changing. For example, something may be advanced in one industry while rudimentary in another, and what is considered advanced today may be obsolete tomorrow. In addition, there is some "advanced" dimension to the activities of virtually any business enterprise. Furthermore, there is some debate as to whether advanced manufacturing should be a product-oriented definition or a process-oriented one. If "advanced" is defined by the product then some sectors such as electronics manufacturing might be considered advanced while other traditional fields like steel production might be considered non-advanced. However, the use of advanced technologies and automated processes are also present in "traditional manufacturing" industries such as textiles and steel manufacturing, and therefore a product-oriented definition might be too narrow.

Following the work of Waldman and Murray (2013), advanced manufacturing is defined as "the application and integration of innovative technologies, materials, and processes to the production of manufactured products (p. 15)." This definition should capture most advanced product industries because of their heavy reliance on R&D (an innovative process) and is also suited to capture advanced processes that use innovative technologies to efficiently manufacture seemingly basic products. Thus, a process-based definition may allow for a broader range of industries to fall into the header of advanced manufacturing.

A second difficulty arises in devising a systematic strategy for identifying which advanced manufacturing industries are good candidates for potential development. One possibility would be to identify advanced manufacturers at the industry level by using wages or output per worker as a proxy. This approach has considerable intuitive appeal since most advanced industrial processes will require a skilled workforce and skilled workers are well paid. In general, output per worker will be highly correlated with worker earnings.

Alternatively, a cluster-based approach, which has become increasingly popular among policymakers and regional economists, can also be used (Porter, 1998). Clusters are groups of industries that are co-located in a specific geographic region and related to each other through common externalities such as a reliance on workers with similar skills, the use of similar inputs, or because they provide related goods and services through the supply chain (Porter, 2003). (It is important to recognize that firms do not need to be engaged in direct trade with one another to be part of the same industrial cluster.) We choose to identify advanced manufacturers through this cluster-based approach because, from a regional perspective, it would be more beneficial to expand an entire cluster of industries rather than one industry within a cluster. Clusters represent interconnected sets of firms or industries where the benefits of one firm can help all industries within the cluster both directly (via supply chain benefits) and indirectly (via agglomeration or the externalities noted above.) Therefore being able to identify and potentially expand an entire cluster can have potentially profound effects on a regional economy.

Clusters and Harvard's Cluster Mapping Project

The cluster approach used here makes use of cluster mapping data from the Harvard Cluster Mapping Project, and helps us obtain a comprehensive picture of all manufacturing industries present across the state of Tennessee. The U.S. Cluster Mapping Project is a federally-funded endeavor led by Michael Porter from the Institute for Strategy and Competitiveness at the Harvard Business School in collaboration with the U.S. Department of Commerce. Their initiative is to identify and characterize regional clusters in order to help build connections within and between industries and facilitate economic growth among regional economies. Major contributions of the project include the development of a comprehensive public database and a user-friendly interface to help policymakers identify and understand industry clusters within a region. Porter has also developed a systematic approach to define which industries are categorized into each cluster (Porter, 2013).

Porter classifies clusters into three broad types of industries based on locational characteristics and competitiveness. First, there are local industries which primarily supply goods and services to the local market or region in which they are located. Local industries only compete in limited ways with industries in other regions and employment is roughly proportional to the regional population. These clusters are in large part comprised of service industries such as health services, hospitality establishments, and utilities, but some non-service industries such as food and beverage processing and construction are also characterized as local.

There are also natural endowment (or resource dependent) industries which are industries located where the needed natural resources are found. These industries can compete with other regions as well as internationally. Examples include mining, forestry, and water transportation industries.

Finally, there are traded industries that are not resource dependent. These industries supply goods and services across the country as well as internationally—i.e. they export their output to other regions. Traded industries base their location decisions on a variety of competitive considerations, including labor costs, worker productivity and spatial logistics, and consequently employment concentration can vary significantly across regions. Examples of traded industries include metal manufacturing, information technology, and biopharmaceuticals.

According to Porter (2000) the presence and strength of these various types of industries (local, natural endowment, and traded) is determined by the region's business environment which can be exemplified by four broad areas: factor conditions; demand conditions; firm strategy, structure, and rivalry; and related and supporting industries (Porter, 2000). Figure 4 illustrates this concept using Porter's diamond model.

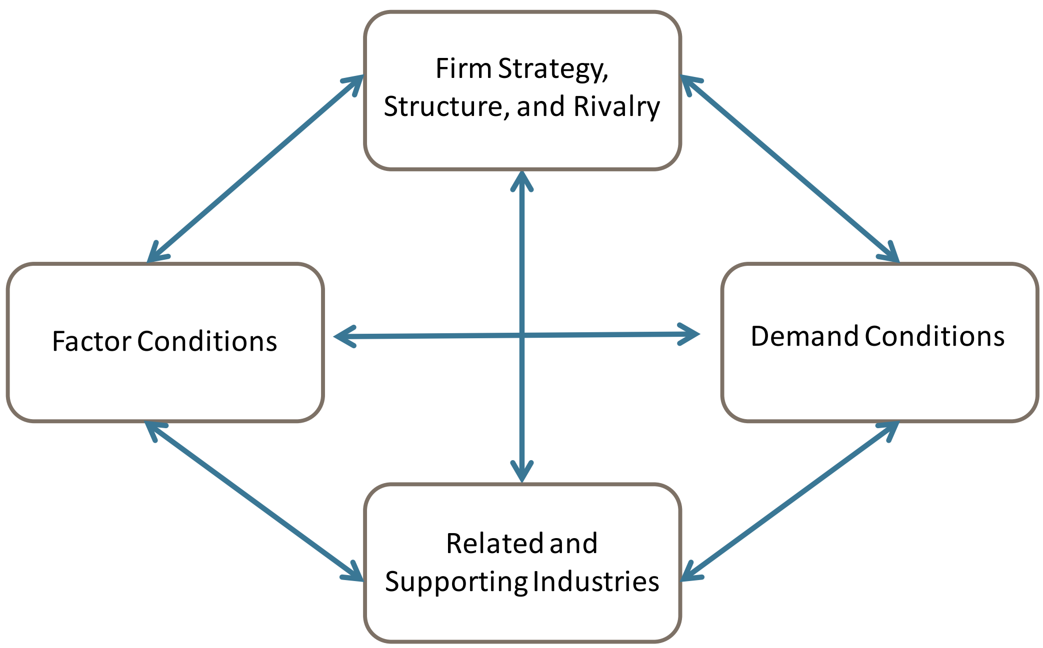
It is important to understand how these aspects can impact the local business environment and how policymakers can improve market conditions through these four facets of the region. "Factor conditions" refer to the regional supply of productive assets such as skilled human resources, physical infrastructure, raw materials, research institutions, and sources of financial capital. High-quality factor conditions can directly improve the region's business environment by enabling firms to become more efficient and more competitive. There are a number of tools that policymakers can use to upgrade the factor conditions of a region. Examples include, but are not limited to, promoting education and setting rigorous standards for teacher qualification, providing direct support to research institutions, incentivizing employee training programs and developing venture capital initiatives. Factor conditions can also be improved by support institutions such as CIS which offers technical assistance to manufacturing firms in a range of performance, growth and sustainability areas.

"Firm strategy, structure, and rivalry" refers to the rules and norms governing local competition. Within this realm, policymakers could improve the business environment by establishing regulations that encourage competition such as tax incentives for capital investments and flexible labor policies.

"Demand conditions" refer to the wants and needs of the local consumers. Stronger demand conditions can stimulate the regional economy and foster growth among local companies. Well-defined consumer protection laws, incentives for customers to become early buyers of new products, and export promotion are ways in which policymakers can stimulate the demand conditions of a region.

Finally, "related and supporting industries" refers to the local suppliers of a region. According to Andersson et al. (2004), "[having] a strong network of suppliers and related industries can increase efficiency and quality through frequent and quick flows of communication … and innovations" (Anderson, p. 160).

Figure 4: Michael Porter's Diamond Model Points to Four Factors Affecting Clusters



Tennessee Manufacturing Clusters

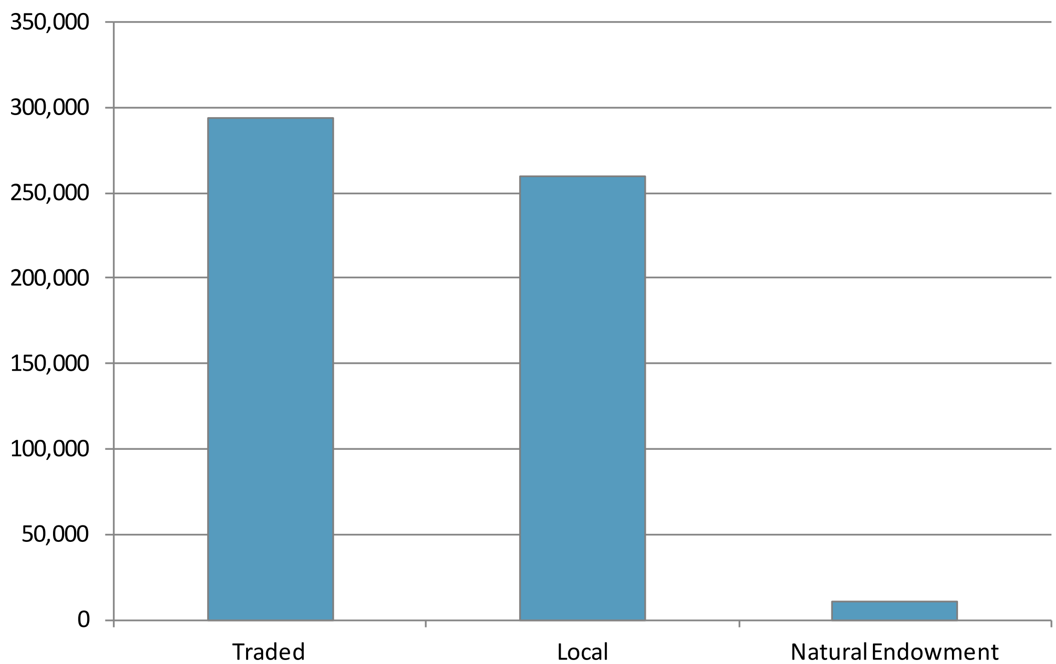
The starting point for the analysis is identification of Tennessee manufacturing clusters using the U.S. Cluster Mapping Project database and Porter's methodology. In the following sections, the discussion shifts to the consideration of factors and data that may help more narrowly identify advanced manufacturing clusters.

A total of 66 clusters were identified in Tennessee in 2011. The cluster mapping database uses data from the U.S. Census Bureau's County Business Patterns dataset, and currently utilizes data from 1998 up to 2011. In 2011 Tennessee's total nonfarm employment was roughly 2.3 million workers or approximately 2.0 percent of national employment. The average wage was $39,896 a year, which was 12.4 percent lower than the national average. One caveat about the 2011 data is that it is likely contaminated, to some extent, by the Great Recession. The Great Recession led to significant structural changes in the national and state economies and restructuring continues to take place. As such, it would be useful to revisit this application again once the economy has stabilized from the recession.

The 66 clusters that are identified represent employment in Tennessee and include workers from service industries as well as other nonmanufacturing sectors such as hospitality and tourism, education, and health services. (While the clusters are based on regions, in practice the region is defined as the state.) The analysis here, however, focuses only on manufacturing industries, and therefore any nonmanufacturing clusters are disregarded. As a result 21 nonmanufacturing clusters are dropped from the sample. In addition, nine smaller clusters are dropped from the sample due to missing data. A list of the 30 clusters excluded from analysis is presented in Appendix Table A.1. This leaves a total of 36 manufacturing clusters in Tennessee, 30 of which are considered traded clusters, 3 are local, and 3 are resource dependent (i.e. natural endowment). A list of the manufacturing clusters is presented in Appendix Table A.2. Total employment in the manufacturing clusters was 564,192 workers in 2011, representing 24.0 percent of Tennessee's total employment. As a supplement to the cluster mapping data we also analyze employment data from the Bureau of Economic Analysis (BEA). Due to the use of Porter's cluster definitions the employment numbers listed above are slightly higher than the manufacturing employment figures listed in the BEA data, (as shown in Figure 1, page 2). This occurs because many of the "manufacturing" clusters contain some service industries which would not be counted in the BEA manufacturing data. For example, the local real estate, construction, and development cluster contains the concrete manufacturing industry but also real estate services and general contractors which are not (and should not) be counted as manufacturing employment in the BEA data. Similarly, the information technology cluster contains computer manufacturing and software development but also communications services, a nonmanufacturing industry.

While there are only three local manufacturing clusters in the state, these local clusters account for approximately 46.0 percent of manufacturing employment in Tennessee (Figure 5). We are much less interested in these clusters because they are not directly involved in production for export. The traded clusters account for 52.0 percent of Tennessee's manufacturing employment, and the natural endowment clusters account for the remaining 2.0 percent. Although the local industries account for a large portion of employment, strength in the traded industries is most essential for prosperity based on the cluster framework (Porter, 2003) as well as basic export-driven models of regional economic development. The average wage in a region, which is a fundamental indicator of economic performance, living standards, and work skills,

Figure 5 Total Employment in Tennessee by Type of Manufacturing Cluster



Source: U.S. Cluster Mapping Project.

was $49,945 among traded industries in Tennessee but only $33,406 for the local industries. (It should be noted that both of these are lower than their respective national averages—the same 30 traded industries had a national average wage of $56,677 and the three local industries had an average wage of $36,983.) Given that employment in the traded industries makes up more than half of Tennessee's manufacturing workforce, and employees in the traded industries get paid, on average, 50.0 percent more than local employees, it seems evident that having a strong traded sector is vital for economic prosperity.

The prosperity of a region however, depends on the productivity of all industries in that region, and therefore policymakers should not neglect local clusters in order to bolster traded ones. The local economy is composed in large part of industries that provide services to the traded clusters (e.g. utilities, transportation, and wholesale trade). Therefore, an inefficient local economy can increase the cost of doing business for the entire region and become a drag on the economy. Thus, strong local clusters support the success of nearby traded clusters. The converse is also true, strong traded clusters can be a boon to the local economy. As traded industries become more productive they will require more support services, thereby creating more jobs in the local economy. Furthermore, Porter (2001) finds that higher wages in traded clusters tend to pull up the wages in the local clusters. While the discussion that follows focuses mostly on traded clusters, a broad economic development strategy would focus on a wider array of business enterprises.

Narrowing the Set of Target Industries: Identification of Potential Clusters for Expansion

As indicated earlier there are some difficulties in defining the term advanced manufacturing. Even with a definition in hand it is also difficult to determine the profile of an advanced manufacturing cluster. For one, advanced manufacturing is a continuum that is both ever-changing and subjective. Secondly, there are little to no data on production processes or capital investments, even at the national level, though both are distinguishing characteristics of an advanced manufacturing cluster. On the other hand, there are data on each cluster's average earnings which is used here as a proxy for identification of advanced industries. The basic rationale is that higher paid workers tend to be more skilled (via formal schooling and/or on-the-job training) and thus more productive. At the same time, industries with higher wages tend to invest more in R&D as well as their overall capital stock. Therefore, clusters with higher paid workers will more likely resemble advanced manufacturers. Aerospace engines manufacturing is a good example of a cluster with a high paid/high skilled workforce. Among other things, aerospace engineering deals with the research, design, and development of air and spacecraft. Working in this field requires advanced knowledge in physics, calculus, trigonometry, and other advanced mathematical topics, and most entry-level aerospace engineer positions require at least a bachelor's degree. In 2011 the average wage for an aerospace engineer in the U.S. was almost $70,000, which was significantly higher than the national average salary of $45,230 in 2011. 1

[2] Bureau of Labor Statistics, Occupational Employment and Wages News Release – May 2011.

In this section four different strategies are discussed that are used to identify manufacturing clusters in Tennessee. These clusters, if nurtured and expanded, could promote greater competition and productivity across the region. Results and insights are presented from each of these approaches. For some of the more established clusters, maps of Tennessee are presented which show where firms of a particular type choose to locate within the state. The U.S. Cluster Mapping Project provides detailed maps at both the national and state levels, but does not provide any micro-level data within a state's borders. Therefore, the data used to create these maps were gathered from the 2011 County Business Patterns survey administered by the U.S. Census Bureau. In the County Business Patterns database each data point is measured at the industry-level and industries are well defined via NAICS codes. Conversely, the U.S. Cluster Mapping data are measured at the more aggregate cluster-level and each cluster contains several industries, each of which has its own unique NAICS code. As a result, there may not be an exact one-to-one relationship between a cluster as defined in the cluster mapping data and a respective industry in the Census data; nonetheless these maps still provide useful information with regards to firm location.

In the first strategy the focus falls on identifying high-wage clusters, i.e. the clusters which will most closely align with advanced manufacturing. The high-wage clusters are characterized by an average wage that was greater than $70,000 in 2011. This was at least 75.0 percent larger than Tennessee's average salary of $39,896 per year in 2011. Increasing job growth among high-wage clusters will certainly have a positive impact on regional income. Moreover, creating new jobs in these high-wage clusters may attract a more educated and higher skilled workforce into the region which could help foster innovation and productivity gains.

In the second strategy the focus is on identifying well-established clusters. The well-established clusters are characterized by a relatively high average wage and a relatively large workforce. The latter is measured using both the absolute number of workers in the cluster as well as the cluster's share of national employment. As a general cut-off point, a cluster's regional workforce must account for roughly 2.0 percent of the cluster's national employment to be considered well-established. These clusters can be viewed as having a good footing in the Tennessee economy and a labor force comprised of higher paid workers. Porter (2003) noted that cluster strength is a strong driver of regional performance and that focusing on established clusters can offer the greatest potential for short-term economic growth. Furthermore, Delgado, Porter, and Stern (2010) found higher rates of new business formation and start-up employment in regions with stronger clusters. Therefore, strengthening established clusters may have a type of multiplier effect whereby increasing employment will not only create new jobs but may also attract new businesses into the region, either directly via the supply chain or indirectly through agglomeration spillovers.

As a third strategy we focus on the clusters with the greatest potential, which are labeled high-potential clusters. These are clusters with a high average wage but small share of the national workforce. These clusters are very productive, and their workers receive high wages, however due to their small size, the overall impact of these clusters on a regional economy is typically small (Porter, 2001).

Finally, as a fourth strategy we focus on identifying aspirational clusters which may need additional support in order to foster growth and greater competition. These are low-wage clusters that may or may not yet be well established in the region. By virtue of being low wage, these clusters do not reflect advanced manufacturing. As such, they are considered aspirational in the sense that policymakers should aspire to making these clusters more advanced for the betterment of the workers, firms, and the region as a whole. The prosperity of a region depends on the productivity of all its industries and not just the performance of the strongest clusters. If a region only focuses on developing its stronger clusters it can become more susceptible to the booms and busts of the business cycle through greater reliance on a subset of the overall economic portfolio. For example, in the 19th and early-20th century Pittsburgh was primarily driven by the steel industry. The raw materials needed for making steel: iron ore, coal, and limestone were all found locally in Pittsburgh. By the 1920s Pittsburgh produced roughly one third of the nation's steel output, and the regional economy was flourishing. However, in the 1980's there was a major downturn in the steel industry and as a result the Pittsburg economy experienced a deep recession and a long-term structural adjustment.

High-Wage Clusters

Using the first strategy, six high-wage clusters are identified in Tennessee. Since average earnings are used as a proxy for advanced manufacturing, these high-wage clusters are most closely aligned with an advanced manufacturing niche in the state. Total employment in the high-wage clusters was 20,235 workers in 2011 and the average wage was $84,170. These clusters—nonmetal mining, aerospace engines, information technology, biopharmaceuticals, power generation and transmission, and aerospace vehicles and defense—along with basic characteristics are listed in Table 1. The composition of each cluster (into subclusters) is then presented in Table 2.

Nonmetal Mining

The first high-wage cluster identified is the nonmetal mining cluster (e.g. coal, gemstones, and gypsum), which had an average wage of $108,749 in 2011. In total there were 2,616 jobs in Tennessee's nonmetal mining cluster. This accounted for 4.7 percent of the nation's nonmetal mining workforce.

From 1998 to 2011 there was a net gain of 424 new nonmetal mining jobs in Tennessee, representing an expansion of 19.3 percent. This compares to a net drop in nonmetal mining employment of 20.2 percent in the nation. Thus, Tennessee's nonmetal mining labor force was growing despite a contraction across the country. Growth in the nonmetal mining cluster also came during a period when total employment in Tennessee's manufacturing clusters contracted by 7.4 percent (between 1998 and 2011) and national manufacturing employment contracted by 19.3 percent. In 2011 Tennessee's nonmetal mining cluster applied for only one patent, but this accounted for 2.63 percent of the nation's nonmetal mining patents.

Table 1: High-Wage Clusters

	TN employment	TN wages	U.S. employment	U.S. wages	TN wage relative to U.S. wage
Nonmetal mining	2,616	$108,749	55,814	$57,965	1.88
Aerospace engines	140	$93,369	79,667	$69,170	1.35
Information technology	9,813	$80,626	846,353	$97,421	0.83
Biopharmaceuticals	4,880	$76,732	247,797	$73,113	1.05
Power generation and transmission	980	$75,273	212,419	$88,286	0.85
Aerospace vehicles and defense	1,806	$70,271	327,453	$82,676	0.85

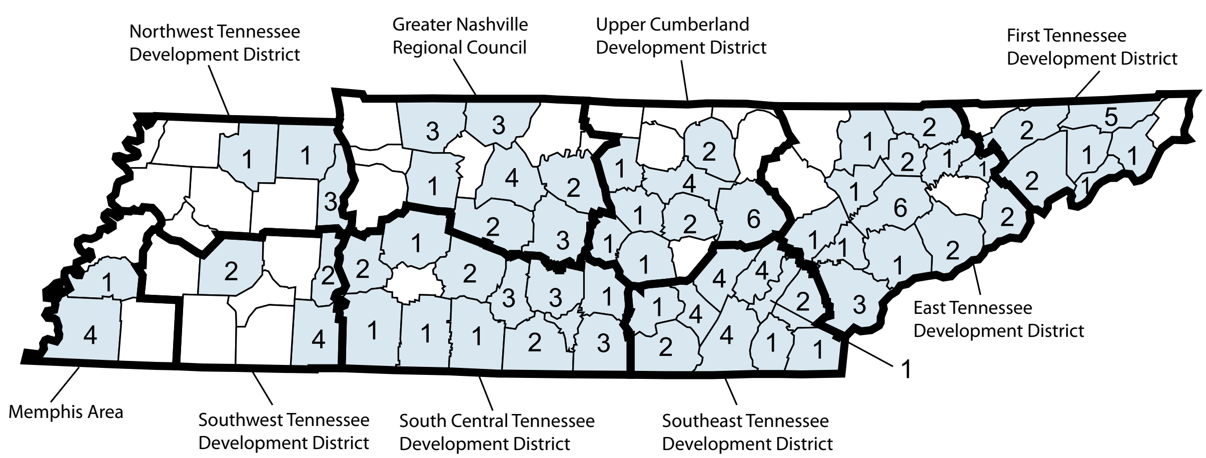
The highest concentration of nonmetal mining firms was located in three East Tennessee counties: Cumberland County which is located in the Upper Cumberland Development District; Knox County, located in the East Tennessee Development District; and Sullivan County of the First Tennessee Development District (see Figure 6.)

While nonmetal mining is categorized as a high-wage cluster, we offer this important caveat. From 1998 through 2010 the average wage in Tennessee's nonmetal mining cluster was never above $50,000, but then in 2011 dramatically increased to $108,749; this was 1.88 times higher than the national average nonmetal mining wage. It is unclear whether nonmetal mining wages in Tennessee will remain high or if this was some aberration, but it is something that should be paid attention to.

Aerospace Engines

The next high-wage cluster is aerospace engines which had an average wage of $93,369. This was significantly

Figure 6: Nonmetallic Mineral Mining and Quarrying Establishments Were Largely Concentrated in East Tennessee, 2011



Source: U.S. Census Bureau, County Business Patterns.

Table 2: High-Wage Clusters and Subclusters

Cluster	Subclusters	Employment	Wage
Nonmetal mining	Nonmetal mining	2,589	$115,197
	Nonmetal mining services	27	$36,148
Aerospace engines	Small arms	130	$93,369
	Aircraft engines	10	Not Disclosed
Information technology	Communications services	7,885	Not Disclosed
	Electronic components and assemblies	760	Not Disclosed
	Peripherals	594	$46,576
	Software	564	$112,261
	Computers	10	Not Disclosed
Biopharmaceuticals	Biopharmaceutical products	2,496	$113,812
	Health and beauty products	1,928	$42,021
	Containers	56	$24,765
Power generation and transmission	Porcelain, carbon and graphite components	435	Not Disclosed
	Turbines and turbine generators	375	Not Disclosed
	Transformers	110	$75,273
	Electric services	60	Not Disclosed
Aerospace vehicles and defense	Aircraft	1,806	$70,271

higher than the national average wage of $69,170 paid to aerospace engine workers. Among all clusters in Tennessee, the aerospace engines cluster was the smallest with only seven firms and a total of 140 workers. This represented a mere 0.18 percent of the nation's aerospace engines workforce. In 2011 there were 117 aerospace engine patents issued in the U.S., however only one originated from Tennessee.

Information Technology

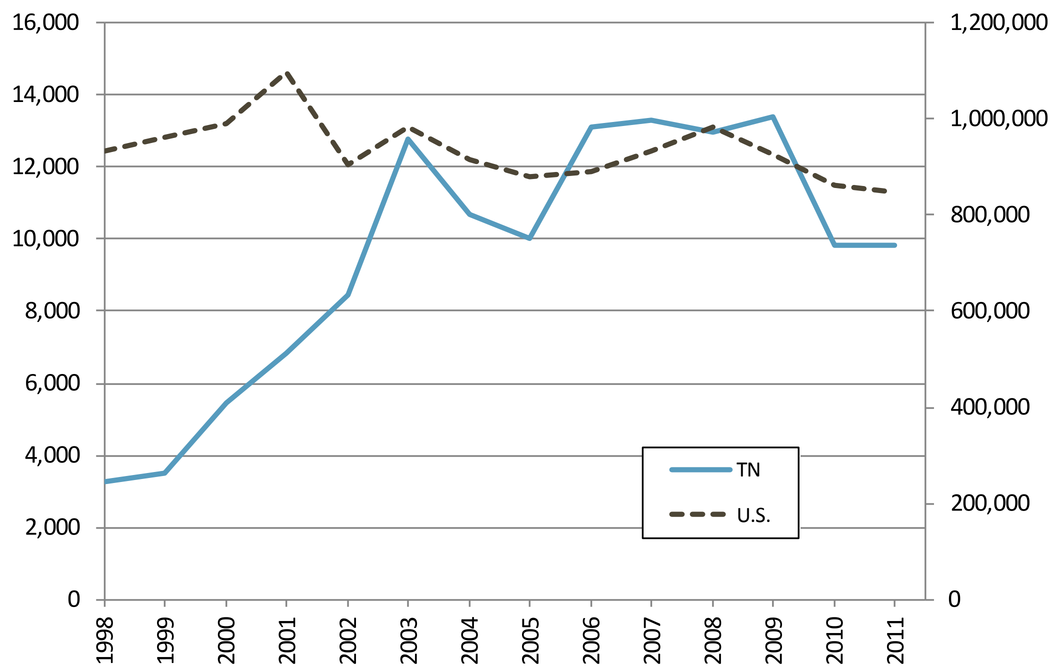
One of the more interesting high-wage clusters in Tennessee is the Information Technology (IT) cluster. This was the largest high-wage cluster in the region with 9,813 employees in 2011. However, this only accounted for 1.2 percent of national employment in IT. In Tennessee the average wage paid to IT workers was $80,626. This was the fourth highest wage among all clusters in the state and third highest among Tennessee's manufacturing clusters. Nevertheless, it was still considerably lower than the national average wage paid in the IT cluster of $97,421. Among all manufacturing clusters in the state, the IT cluster experienced the fastest job growth by a large margin. Between 1998 and 2011, 6,566 new jobs were created which represented a 202 percent job growth rate. The majority of these jobs were created between 1999 and 2003 which was in the height of the dot-com era. In more recent years there was a slight contraction of the labor force due to the recent recession. Interestingly the IT labor force was strongly affected by the recent recession but not at all during the recession in the early-2000s. In fact the industry grew in spite of the first recession of the 21st century. This of course was due to the advanced development of technology and more specifically the internet during the late-90s and early-2000s. Figure 7 plots employment in the IT cluster over time for both Tennessee and the U.S. Employment fluctuated significantly in Tennessee relative to the nation.

Within the IT cluster one of the more interesting components is the peripherals subcluster. Peripherals include any device that is connected to a computer but is not part of the computer, such as a mouse, keyboard, or printer. In 2011 there were only 594 employees in Tennessee's peripherals industry, making it one of Tennessee's smaller manufacturing industries. However, what makes the peripherals industry so interesting is the development of the 3D printer which has the potential to change the entire landscape of the manufacturing industry.

Biopharmaceuticals

The next high-wage cluster is biopharm-aceuticals which had an average wage of $76,732 in 2011. This was in line with the national average salary for biopharmaceutical workers but more than double the average salary of $39,896 amongst all Tennessee employees in 2011. Tennessee's biopharmaceuticals cluster had a total of 4,880 employees which accounted for nearly 2.0 percent of the nation's biopharmaceutical employment. Between 1998 and 2011, employment in U.S. biopharmaceuticals fell by 4.2 percent. This overall contraction was apparent in Tennessee's economy as job growth in the state's biopharmaceutical cluster fell by 3.6 percent. From 1998 to 2011, 265 additional biopharmaceutical establishments opened across the country, however, only nine were located in Tennessee. In total there were only 34 biopharmaceutical establishments located in Tennessee in 2011.

Figure 7: U.S. and Tennessee Employment in Information Technology Cluster, 1998 to 2011



Source: U.S. Cluster Mapping Project

The biopharmaceutical cluster consisted of three subclusters. The health and beauty products subcluster which employed 1,928 workers with an average wage of $42,021, biopharmaceutical products which employed 2,496 workers with an average wage of $113,812, and containers which employed 56 workers at an average wage of $24,765. Within this cluster, expansion of the biopharmaceutical products subcluster would probably be the most beneficial due to the high wages paid in this subcluster.

Power Generation and Transmission

In Tennessee the power generation and transmission (PG&T) cluster paid an average wage of $75,273 in 2011. This was significantly less than the national average wage of $88,286 paid to PG&T workers. Tennessee's PG&T labor force consisted of 980 employees which accounted for only 0.46 percent of the nation's PG&T labor force. In 2011 there were 677 new patents issued to PG&T firms across the nation, but only four were to companies located in Tennessee.

Between 1998 and 2011, employment in the U.S. PG&T cluster contracted by roughly 10.4 percent. This contraction was even more pronounced in Tennessee which faced a contraction of 61.6 percent. In total there were 19 PG&T establishments located in Tennessee in 2011. This was down from 25 establishments in Tennessee in 1998.

Aerospace Vehicles and Defense

In Tennessee, the aerospace vehicles and defense cluster paid an average wage of $70,271. This was roughly $12,000 less than the average wage paid to aerospace vehicles and defense workers across the country.

This cluster had a total of 1,806 employees in Tennessee, which accounted for 0.85 percent of the nation's aerospace vehicles and defense labor force. Between 1998 and 2011 aerospace vehicles and defense employment fell by 25.7 percent in the U.S. This contraction was felt noticeably in Tennessee as well, where aerospace vehicles and defense employment fell by 51.0 percent. Despite this contraction in the labor force there was an increase in the number of establishments operating in Tennessee from 17 in 1998 to 22 in 2011. In 2011 there were 565 aerospace vehicles and defense patents issued in the U.S., but only three of these originated in Tennessee.

3D Printing

3D printing is done using a process known as "additive manufacturing," whereby virtually any solid object can be created from a digital model. The process starts when a computer-aided design (CAD) image is sent to the 3D printer. Special CAD software is used to "slice" the three-dimensional object into digital cross-sections which the printer can use as a blueprint. Using these cross-sections the printer then lays successive layers of material (wax, plastic, metal, or some composite material) down onto a surface and builds the model from scratch.

Traditionally, manufacturing has been done using a "subtractive process" where the manufacturer starts with a solid block or sheet of material and cuts, drills, or shaves it into the desired shape. In contrast, 3D printing relies on a more advanced "additive process" to create products from the bottom up by adding layer after layer of new material.

This process allows individuals to create objects without the need for a factory or shop filled with tools. In fact, desktop 3D printers have been developed and enable individuals to manufacture new products within the confines of their own home or office. At the same time, firms are starting to make more use of 3D printing. Aerospace engineers are using 3D printers to develop lighter, more fuel efficient airplane parts and medical device manufacturers are building customized prosthetics. For now, 3D printing is still in a niche market. It has proven useful to millions of hobbyists as well as firms looking to build customized products. While it is not yet used broadly in mass production, it has become a booming industry. According to Goldman Sachs, 3D printing is currently a $2.2 billion market with forecasted revenue of $10.8 billion by 2021 (Goldman Sachs, 2013). Moreover, analysts at McKinsey Global Institute estimate that 3D printing could generate an economic impact of $230 billion to $550 billion per year by 2025 (Manyika et al., 2013).

Well-Established Clusters

As a second strategy we identified six well-established clusters where expansion could be beneficial to the regional economy. The well-established cluster includes firms that pay a relatively high average wage and have a relatively large workforce. Total employment in the well-established clusters was 75,403 workers and the average wage was $66,837. These clusters—nonmetal mining, biopharmaceuticals, chemical products, medical devices, metal manufacturing, and forest products—along with basic characteristics are listed in 3. The composition of each cluster (into subclusters) is then presented in Table 4.

Since these clusters have a larger presence in Tennessee we can also gain valuable information by looking at where these clusters are located within the state and whether any particular locational patterns emerge. Note that there are two clusters in the well-established category that were also identified in the high-wage category, nonmetal mining and biopharmaceuticals. To avoid repetition, we do not discuss the details of these two clusters any further.

Chemical Products

In 2011 the largest well-established cluster was the chemical products cluster which employed 32,668 workers in Tennessee. This accounted for nearly 10.0 percent of the nation's chemical products workforce and represented the largest share of national employment among all clusters in the state. The average wage paid to chemical product workers in Tennessee was $60,286, which was slightly below the national average of $66,785. Between 1998 and 2011, employment in Tennessee's chemical products cluster fell by 5.3 percent. This was far less dramatic than the 28.6 percent drop in chemical products employment that was felt across the country (see Figure 8.)

The chemical products cluster consisted of six subclusters and the majority of workers were employed in the intermediate chemicals and gases subcluster. This subcluster contained 9,375 workers and paid an average wage of $80,005. Within the chemical products cluster an expansion of the intermediate chemicals subcluster would likely be most beneficial in the near-term because it is the most established and offers the highest average wage. Examples of intermediate chemical manufacturing firms in Tennessee include the Eastman Chemical Company which is based in Kingsport and the Dupont Tate and Lyle Bio Products biochemical plant in Loudon. The highest concentration of chemical product firms, by a large margin, was located in Shelby County followed by Hamilton County (see Figure 9.)

Medical Devices

The medical devices cluster is another well-established cluster in Tennessee and employed 8,128 workers at an average wage of $60,090 in 2011. This accounted for 2.1 percent of the nation's employment in medical device industries. Among medical device workers, the average Tennessean was paid slightly less than the national average wage of $68,835. Between 1998 and 2011, national employment in the medical devices cluster expanded by 6.4 percent. In Tennessee however, job growth expanded at a far more rapid pace of 48.8 percent, making medical devices one of the fastest growing clusters in the state over the last decade. In 2011 there were 107 medical device

Table 3: Well-Established Clusters

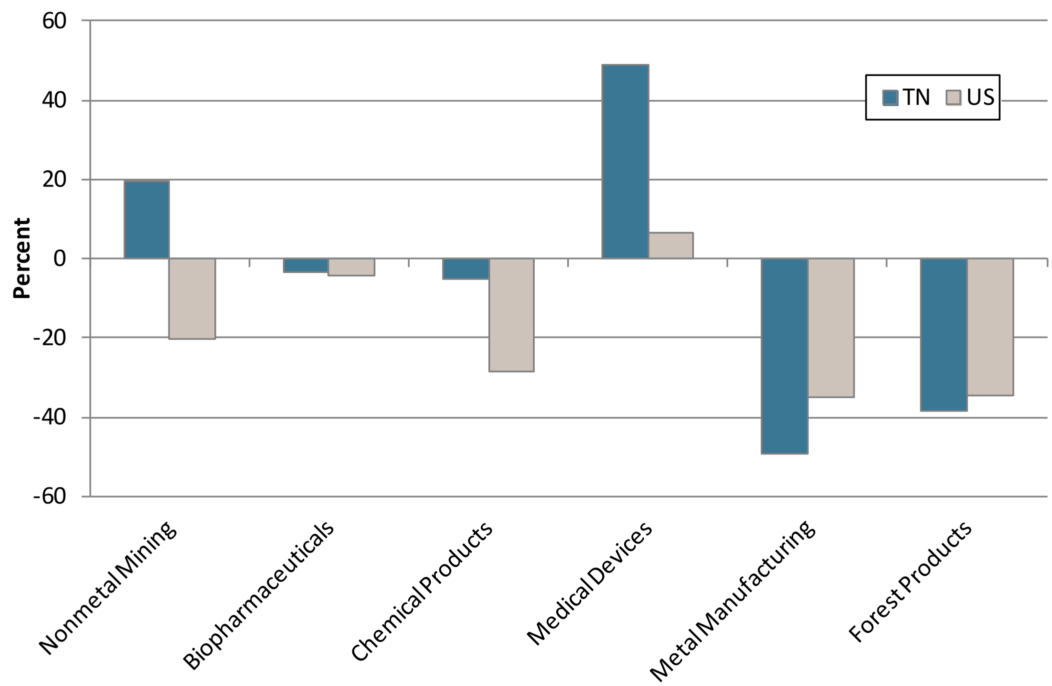
	TN employment	TN wages	U.S. employment	U.S. wages	TN wage relative to U.S. wage	Share of U.S. employment (percent)
Nonmetal mining	2,616	$108,749	55,814	$57,965	1.88	4.69
Biopharmaceuticals	4,880	$76,732	247,797	$73,113	1.05	1.97
Chemical products	32,668	$60,286	340,784	$66,785	0.9	9.59
Medical devices	8,128	$60,090	386,589	$68,835	0.87	2.1
Metal manufacturing	18,436	$47,629	908,117	$52,209	0.91	2.03
Forest products	8,675	$47,533	281,167	$53,827	0.88	3.09

Table 4: Well-established Clusters and Subclusters

Cluster	Subcluster	Employment	Wage
Chemical products	Intermediate chemicals and gases	19,375	$80,005
	Ammunition	7,549	$21,718
	Other processed chemicals	2,707	$56,990
	Packaged chemical products	2,409	$49,007
	Special packaging	375	Not disclosed
	Refractories	193	$43,268
	Leather tanning and finishing	60	Not disclosed
Medical devices	Surgical instruments and supplies	5,854	$65,341
	Ophtalmic goods	909	$35,548
	Medical equipment	810	Not disclosed
	Dental instruments and supplies	320	$33,747
	Biological products	175	Not disclosed
	Diagnostic substances	60	Not disclosed
Metal manufacturing	Metal processing	4,015	$42,541
	Fabricated metal products	2,810	$46,755
	Iron and steel mills and foundries	2,264	$71,446
	Nonferrous mills and foundries	2,095	$46,274
	Precision metal products	1,747	$45,414
	Wire and springs	1,651	$35,227
	General industrial machinery	1,194	$52,080
	Fasteners	1,189	$55,336
	Metal furniture	829	$34,007
	Laundry and cleaning equipment	435	Not disclosed
	Environmental controls	147	$47,959
	Pumps	60	Not disclosed
Forest products	Paper products	2,811	$34,640
	Paper mills	2,621	$73,469
	Prefabricated wood products	2,337	$32,498
	Brooms and brushes	750	Not disclosed
	Paper industry machinery	156	$38,372

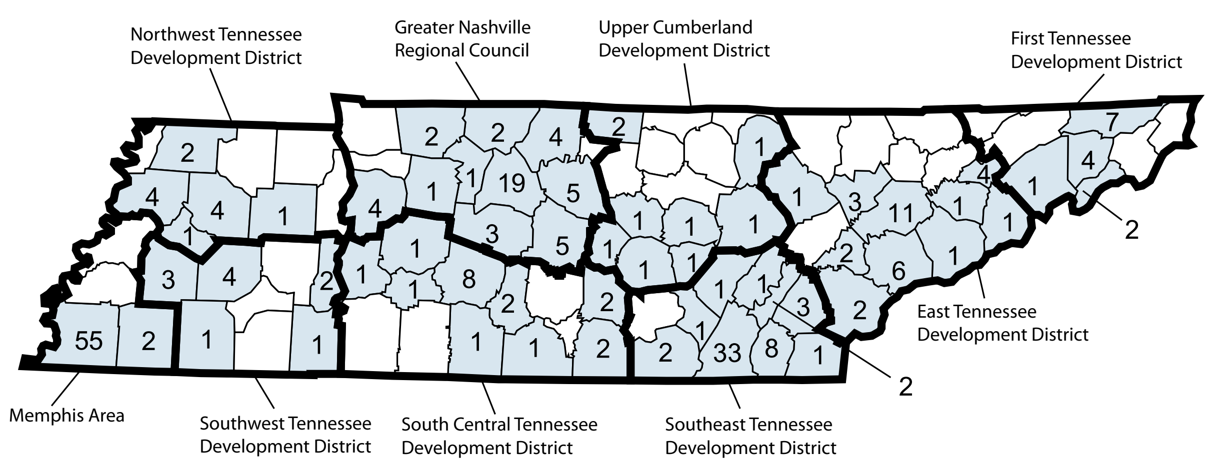
*Note: any clusters that were identified as both *well-established* and *high-wage* clusters are listed in Table 4.2.

Figure 8: Job Growth per Sector 1998 to 2011



Source: U.S. Cluster Mapping Project.

Figure 9: Chemical Manufacturing Establishments Were Concentrated Near Memphis, Chattanooga, Nashville, and Knoxville, 2011



Source: U.S. Census Bureau, County Business Patterns.

establishments located in the state; this was up from 100 in 1998.

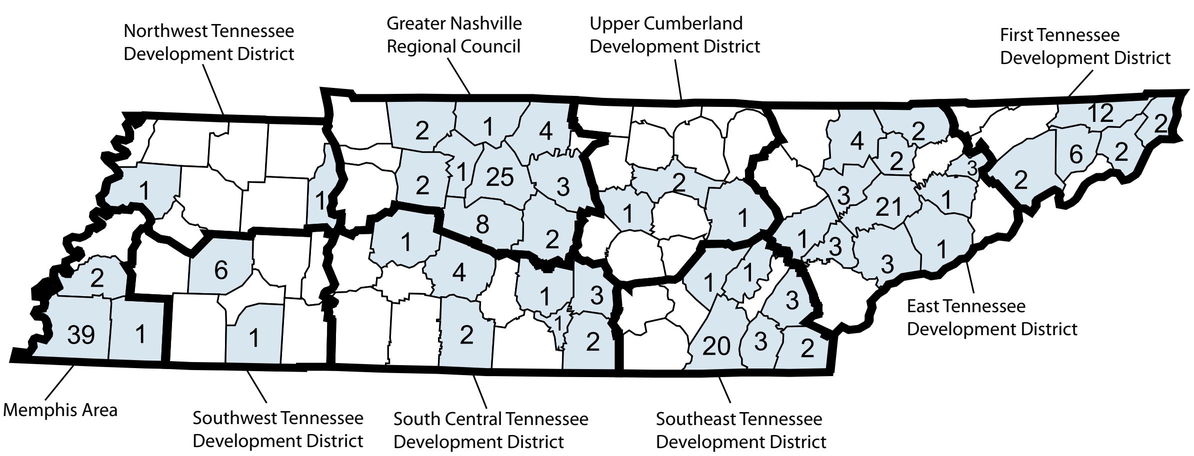
The medical devices cluster consisted of six subclusters, the largest of which was the surgical instruments and supplies subcluster which employed 5,854 workers and paid an average wage of $65,341. Other medical device subclusters included ophthalmic goods, medical equipment, dental instruments and supplies, biological products, and diagnostic substances. Each of these five subclusters had employment of less than 1,000 workers and the average wage was either below $36,000 or was not disclosed. The highest concentration of medical device firms was in Shelby County where 39 establishments were located. Most of these were likely located in close proximity to the University of Tennessee's Health Sciences Center in Memphis. In addition there was a high concentration of medical device firms located in Davidson and Williamson County (Nashville), Knox County (Knoxville), and Hamilton County (Chattanooga) (see Figure 10); indicating that the majority of medical device firms were located in or near the major metropolitan areas and major universities.

Metal Manufacturing

Another well-established cluster in Tennessee is metal manufacturing, which had 18,436 employees in 2011. The average wage in this cluster was $47,629. This was slightly below the national average wage of $52,209 paid to metal manufacturing workers, but still above Tennessee's aggregate average wage of $39,896 and also above the U.S. aggregate average of $45,535. Between 1998 and 2011, employment in metal manufacturing fell across the nation. However, this period was especially tough for Tennessee where nearly 18,000 jobs were lost, representing a contraction of 49.3 percent. Similarly, there were 574 metal manufacturing establishments located in Tennessee in 1998 but in 2011 there were only 466, reflecting a drop of 18.8 percent.

The metal manufacturing cluster is quite diverse as it is comprised of 12 subclusters. In 2011, the largest subcluster was metal processing which employed over 4,000 workers. However, the highest paying subcluster was the iron, steel mills, and foundries subcluster which paid an average salary of $71,446 and employed 2,264 workers. The majority of other subclusters in metal manufacturing had an average wage that ranged from $42,000 to $55,000.

Figure 10: Medical Equipment and Supplies Manufacturing Establishments Were Located Near Major Metropolitan Areas, 2011



Source: U.S. Census Bureau, County Business Patterns.

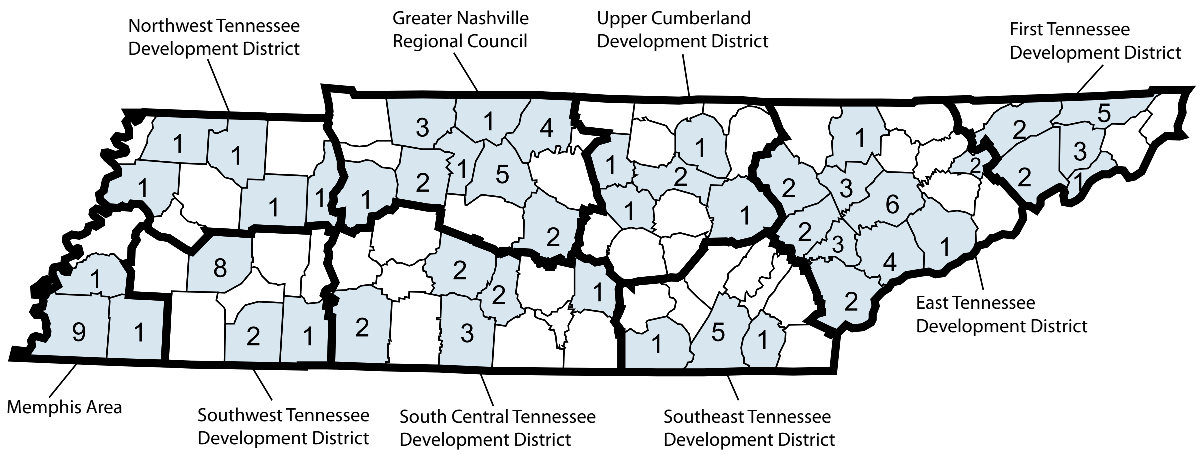
The highest concentration of metal manufacturing firms was located in Western Tennessee in Shelby County (Memphis Area Development District) and Madison County (Southwest Tennessee Development District). Though there was also a relatively high concentration located in Knox County (East Tennessee Development District) and its surrounding areas (see Figure 11.)

Forest Products

The final cluster identified as well-established is the forest products cluster which employed 8,675 Tennessee workers in 2011. This represented 3.1 percent of the nation's employment in forest products. The average wage paid to forest product workers was $47,533 in Tennessee. This was slightly less than the national average of $53,827 paid to forest product workers, but still significantly higher than Tennessee's overall average wage of $39,896. Between 1998 and 2011, employment in the forest products cluster fell by 34.5 percent across the nation and by 38.4 percent in Tennessee. Similarly, there were 174 forest product establishments located in Tennessee in 1998 but only 122 in 2011.

The forest products cluster consisted of six subclusters, three of which employed at least 2,000 workers in 2011. Most notably, the paper mills subcluster employed 2,621 workers and paid an average wage of over $73,000. Within the forest products cluster, expansion of the paper mills subcluster would probably be most beneficial to Tennessee because it was the only high paying subcluster in the group. The two other subclusters with 2,000-plus employees were the paper products subcluster and prefabricated wood products. However, both of these subclusters had an average wage that was less than $35,000. Unfortunately, County Business Patterns offers no county-level detail for the forest products industry.

Figure 11: Primary Metal Manufacturing Establishments Were Largely Concentrated in West Tennessee, 2011



Source: U.S. Census Bureau, County Business Patterns.

High-Potential Clusters

As a third strategy, we identified a group of high-potential clusters, which are clusters with a high average wage but a small share of the nation's workforce. The small national workforce share indicates that larger versions of these clusters do exist in other states and hints towards an opportunity for growth. This could be accomplished by setting sights on attracting firms to relocate operations into Tennessee, by starting new firms, or by expanding existing operations within the Tennessee border. In any case, there is an existing demand for these products and the region could benefit from becoming more active in these markets. With a proper strategy and sufficient support, high-potential clusters today could become well-established clusters tomorrow.

The majority of high-potential clusters are high-tech clusters with a relatively small workforce. A new job in one of these high-tech clusters represents additional income to the region that is nearly twice as large as the region's average wage. Furthermore, employees in high-tech clusters generally possess higher levels of education and a greater skillset. Attracting more of these workers into the region can lead to higher rates of innovation which can stimulate productivity and ultimately lead to greater prosperity for the cluster and the region.

Six clusters are identified as high-potential. Total Tennessee employment in these clusters was 8,819 workers in 2011 and the average wage was $68,450. Each of these clusters had less than a one percent share of the cluster's national employment and the average share was 0.45 percent. There was some overlap between the high-wage clusters and high-potential clusters. Specifically, aerospace engines, aerospace vehicles and defense, and power generation and transmission were identified in both categories. However, three new clusters: analytical instruments, communications equipment, and oil and gas products and services also emerged. Basic characteristics of all six high-potential clusters are presented in Table 5 and a more detailed breakdown of the composition of the three new clusters is presented in Table 6.

Table 5: High-Potential Clusters

	TN employment	TN wages	U.S. employment	U.S. wages	TN wage relative to U.S. wage	Share of U.S. employment (percent)	TN patents	Share of U.S. patents (percent)
Aerospace engines	140	$93,369	79,667	$69,170	1.35	0.18	1	0.85
Power generation and transmission	980	$75,273	212,419	$88,286	0.85	0.46	4	0.59
Aerospace vehicles and defense	1,806	$70,271	327,453	$82,676	0.85	0.55	3	0.53
Oil and gas products and services	1,270	$65,755	602,274	$91,873	0.72	0.21	2	0.52
Analytical instruments	3,485	$55,433	487,168	$74,199	0.75	0.72	69	1.05
Communications equipment	1,138	$50,599	186,659	$74,846	0.68	0.61	42	0.32

Table 6: High-Potential Clusters and Subclusters

Cluster	Subclusters	Employment	Wage
Oil and gas products and services	Pipeline transportation	445	Not disclosed
	Petroleum processing	435	Not disclosed
	Oil and gas exploration drilling	256	$63,776
	Hydrocarbons	124	$69,158
	Oil and gas machinery	10	Not disclosed
Analytical instruments	Electronic components	1,508	$51,053
	Process instruments	1,399	$60,225
	Laboratory instruments	494	$58,336
	Search and navigation equipment	74	$71,135
	Optical instruments	10	Not disclosed
Communications equipment	Electrical and electronic components	778	$50,599
	Communications equipment	185	Not disclosed
	Specialty office machines	175	Not disclosed

*Note: any clusters that were identified as both high-potential and high-wage clusters are listed in Table 4.2.

Aspirational Clusters

Finally, we identified a group of low-wage clusters which are labeled as aspirational. These clusters all had an average wage that was lower than the state average of $39,896. However, not all of these aspirational clusters represented traditionally low paying jobs; in many cases the national average wage was significantly higher than the wage paid in Tennessee.

Thirteen aspirational clusters were identified in the state. In total there were 172,107 employees working in these aspirational clusters, and the average wage was $32,220. Basic characteristics of the aspirational clusters are presented in Table 7 and a more detailed breakdown on the composition of each cluster is presented in Table 8.

Among all four identification strategies, the largest number of clusters was identified into this aspirational category. Furthermore, some of the largest clusters, as measured by labor force size, were also identified as aspirational. This illustrates that a large portion of the Tennessee workforce was employed in lower paying occupations. As noted above, the aspirational cluster does not capture advanced manufacturing. But these same firms could conceivably benefit significantly from advanced manufacturing practices. Identifying and expanding these aspirational clusters could be a successful strategy for long-term sustainable growth in the region simply due to the large number of workers that could stand to benefit. For example, one of the larger clusters in the aspirational group was the motor driven products cluster (e.g. refrigerators, heaters, and other motorized machinery), which had a labor force of over 20,000 workers. This accounted for 8.6 percent of the nation's labor force in motor driven products. In Tennessee the average wage paid to these workers was almost $10,000 lower than the national average paid to motor driven product workers. Narrowing this wage gap could have a large positive effect on living standards in Tennessee. Specifically, an incremental increase in the wages of a large group could produce wealth effects that have a profound impact on the region's economy. While identifying some of these aspirational clusters is straightforward, determining ways to increase firm profitability, competitiveness, and earnings is challenging.

Table 7: Aspirational Clusters

	TN employment	TN wages	U.S. employment	U.S. wages	TN wage relative to U.S. wage	Share of U.S. employment (percent)	TN patents	Share of U.S. patents (percent)
Motor driven products	20,066	$39,001	234,141	$48,852	0.8	8.57	23	1.5
Sporting, recreational and children's goods	578	$36,134	55,385	$45,507	0.79	1.04	3	0.82
Prefabricated enclosures	6,283	$35,517	141,951	$42,813	0.83	4.43	3	0.89
Leather and related products	1,679	$34,785	86,245	$43,680	0.8	1.95	4	1.14
Construction materials	4,799	$33,433	143,842	$37,983	0.88	3.34	7	1
Local household goods and services	33,005	$30,961	1,742,828	$33,032	0.94	1.89	1	1.56
Furniture	6,172	$29,049	166,336	$32,627	0.89	3.71	3	1.69
Livestock processing	6,513	$27,594	222,666	$27,106	1.02	2.92	1	2.22
Forestry and primary wood processing	1,172	$27,165	85,920	$41,827	0.65	1.36	0	0
Local food and beverage processing and distribution	73,684	$25,832	4,028,492	$28,405	0.91	1.83	1	0.84
Apparel	3,789	$23,511	120,251	$26,980	0.87	3.15	2	1.04

Table 8: Aspirational Clusters and Subclusters

Cluster	Subcluster	Employment	Wage
Motor driven products	Refrigeration and heating equipment	6,689	$42,708
	Appliances	6,325	$33,593
	Tires	3,750	Not disclosed
	Motorized equipment	1,972	$42,231
	Motors and generators	720	$31,765
	Batteries	375	Not disclosed
	Specialized pumps	175	Not disclosed
	Specialized machinery	60	Not disclosed
Jewelry and precious metals	Jewelry and precious metals products	347	$38,711
	Cutlery	175	Not disclosed
	Costume jewelry	60	Not disclosed
	Collectibles	10	Not disclosed
Building fixtures, equipment and services	Wood cabinets, fixtures and other products	4,239	$32,082
	Furniture and fittings	2,876	$35,401
	Plumbing products	2,809	$35,574
	Fabricated materials	1,742	$49,897
	Heating and lighting	752	$42,020
	Concrete, gypsum and other building products	747	$41,143
	Steam and air conditioning	375	Not disclosed
	Clay and vitreous products	175	Not disclosed
	Drapery hardware	60	Not disclosed
Sporting, recreational and children's goods	Sporting and athletic goods	369	$35,482
	Motorcycles and bicycles	199	$37,342
	Games, toys, and children’s vehicles	10	Not disclosed
Prefabricated enclosures	Aluminum processing	1,750	Not disclosed
	Mobile homes	1,750	Not disclosed
	Caskets	750	Not disclosed
	Elevators and moving stairways	750	Not disclosed
	Recreational vehicles and parts	583	$27,775
	Trucks and trailers	350	$44,543
	Household refrigerators and freezers	175	Not disclosed
	Office furniture	175	Not disclosed
Leather and related products	Related products	787	$33,478
	Leather products	472	$25,498
	Coated fabrics	360	$43,497
	Accessories	60	Not disclosed
Construction materials	Wood products	1,976	$25,956
	Rubber products	1,316	$45,340
	Tile, brick and glass	925	Not disclosed
	Cut and crushed	572	$31,705
	Plumbing fixtures	10	Not disclosed

Conclusion

Cluster-based approaches to regional economic development have become commonplace in recognition of agglomeration spillovers and supply-chain linkages across firms and industries. An important implication of this approach is that improvements in the competitiveness of one firm can yield important benefits for other firms and the region within which the cluster is located.

Advanced manufacturing is an emerging component of the industrial sector and in principle lends itself to examination through the lens of regional clusters. However, advanced manufacturing is in practice difficult to define and identify with available data. This report uses a process-oriented definition of advanced manufacturing that allows industry identification indirectly through metrics such as worker earnings and patent activity. Worker earnings are generally associated with higher levels of formal education and on-the-job training and greater capital investment of firms, and thus have an important bearing on productivity and firm competitiveness. Patenting is illustrative of research and knowledge development that also enhances production processes and productivity.

Using the cluster approach, four different candidate sets of clusters are identified that may offer promise through policy support and technical assistance. The most promising from an advanced manufacturing perspective is the high-wage cluster where firms and industries are isolated based on their earnings relative to the statewide average. Also identified is a well-established cluster that accounts for a large share of state employment and relatively high earnings, a high-potential cluster where earnings are high but the state's share of national employment is small, and an aspirational cluster of industries and firms that pays relatively low wages but could nonetheless benefit from productivity-enhancing improvements to production processes. The identification of clusters and their associated characteristics should help policymakers and providers of technical assistance better target their scarce resources that are intended to promote economic development in Tennessee. Future questions for consideration include: Which clusters are more likely to invest in technical assistance from university and state service providers? Are there relationships between cluster and ownership structure, interest in technology transfer and growth, defined supply chains, etc.? What services for each sector are more conducive to manufacturing employment? This study provides a foundation for continuing efforts to understand how policy makers and service providers can better serve Tennessee's manufacturers.

Appendix

Table A.1: Clusters excluded from sample

Nonmanufacturing
Business services
Distribution services
Education and knowledge creation
Entertainment
Financial services
Hospitality and tourism
Local commercial services
Local community and civic organizations
Local education and training
Local entertainment and media
Local financial services
Local health services
Local hospitality establishments
Local industrial products and services
Local logistical services
Local motor vehicle products and services
Local personal services (non-medical)
Local retail clothing
Local utilities
Publishing and printing
Transportation and logistics
Missing Data
Agricultural products (resource dependent)
Coal mining
Combination energy services
Fertilizers
Fishing and fishing products
Footwear
Metal mining
Tobacco
Water transport

Table A.2: Manufacturing Clusters in Tennessee

Aerospace engines
Aerospace vehicles and defense
Agricultural products
Analytical instruments
Apparel
Automotive
Biopharmaceuticals
Building fixtures, equipment and services
Chemical products
Communications equipment
Construction materials
Forest products
Forestry and primary wood processing
Furniture
Heavy construction services
Heavy machinery
Information technology
Jewelry and precious metals
Leather and related products
Lighting and electrical equipment
Livestock processing
Local food and beverage processing and distribution
Local household goods and services
Local real estate, construction, and development
Medical devices
Metal manufacturing
Motor driven products
Nonmetal mining
Oil and gas products and services
Plastics
Power generation and transmission
Prefabricated enclosures
Processed food
Production technology
Sporting, recreational and children's goods
Textiles

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