Technology-Intensive Manufacturers in Virginia: Performance and Prospects

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Virginia's Center for Innovative Technology

VIRGINIA MANUFACTURERS ASSOCIATION

Table of Contents

Acknowledgments

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Executive Summary

I. Introduction

As firms and entire industries continue to navigate their way through the challenges and opportunities posed by commerce in the new millennium, policy makers have been working overtime trying to gain insight into the ways in which the public sector might best support these private sector labors. This report is focused on answering one central question. How can we help our private sector generate higher wage job opportunities for our citizens and more wealth in our communities?

It is apparent that manufacturing is still a very potent wealth-generating engine in developed economies. Manufacturing sector average wage rates are much higher than all other sectors. More importantly, perhaps, manufacturing innovation drives innovation and growth in the other sectors – including the service sector. Within the manufacturing sector itself, research and development (R&D) activities appear to be particularly important. This is because manufacturing R&D drives the productivity of firms that routinely engage in it; generates and supports high wage, high impact jobs; advances and spawns innovation within local and regional economies; and increases the competitiveness of regional economies, enhancing their attractiveness as a place to locate, relocate, or expand.

In the course of pursuing its mission to support technology-based economic growth, Virginia's Center for Innovative Technology (CIT) recognized that dramatic changes in the world economy over the last two decades meant big shifts in the complexity and pace of the markets in which its manufacturers were competing. The Commonwealth's technology-intensive manufacturing community was of particular concern – especially those firms with higher levels of R&D activities. How have these firms fared in Virginia over the last decade? What can be done in the future (if anything) to help them become more competitive in general and, in particular, what factors affect the vitality of their R&D functions within the Commonwealth? For these kinds of manufacturing firms, what factors influence their decision to locate or relocate in Virginia or to expand or contract existing operations, especially their R&D functions?

To answer these questions, new information and a fresh perspective on technology-intensive manufacturing in Virginia was needed. As such, CIT engaged Regional Technology Strategies, Inc. to help them:

(1) Assess the performance, over the most recent ten-year period for which data were available, of the Commonwealth's technology-intensive manufacturing community (with particular attention to jobs in manufacturing-related R&D);

(2) Identify the factors that seem to exert the strongest influence over these companies' decisions to re-locate, expand, contract or startup in Virginia; and

(3) Identify potential public policy directions and actions that stand the greatest chance of advancing the competitiveness and growth of the Commonwealth's existing technology-intensive manufacturing community as well as making Virginia a more attractive location for these kinds of firms.

II. Methodology and Scope: Focus on Technology-Intensive Manufacturing

The data analyzed for the study come from two major sources: (1) ES-202 employment and establishment datasets, and (2) a mail survey administered to a sample of 325 technology-intensive manufacturing companies in Virginia.

The scope of the project was limited to examining the performance, roles, and prospects of manufacturing firms in the 34 industries defined as technology-intensive by the Bureau of Labor Statistics (for a list of these industries, see Appendix A). The goal was to develop a better and deeper understanding of this critical segment of the Commonwealth's technology landscape, in order to (1) more effectively highlight its role within Virginia's economy, and (2) lay the foundation for crafting more effective strategic public policy actions (if warranted).

This particular slice of Virginia's manufacturing community was highlighted for closer study for two reasons: because of its powerful capacity to generate income, wealth, and innovation; and, perhaps more importantly, because of its very valuable contribution to the competitiveness of the Commonwealth's overall manufacturing base. Even though technology-based firms in a variety of service industries are and will be major sources of employment and output growth within Virginia's economy, this effort addressed only technology-intensive manufacturing.

III. Key Findings and Conclusions

A. The Role of Technology-Intensive Manufacturing and Manufacturing R&D

(1) At the national level, declines in manufacturing employment and GDP share are due to the very qualities that make manufacturing important to the U.S. economy.

As manufacturing industries become more productive, they need fewer employees to produce a given increase in output (manufacturing's workforce share declined from 28 percent in 1970 to 18 percent in 1998.) The service sector, where productivity is growing less quickly, requires relatively more employees to increase output, heightening the shift in employment from manufacturing to services.[1] The same effect holds for manufacturing's declining share of GDP (currently at 20 percent); as manufacturing output is produced more efficiently, manufactured goods can be sold at increasingly lower cost. This results in lower domestic expenditures on manufactures relative to services, which are still relatively higher-priced. The lower cost of manufactured goods contributes to the nation's rising standard of living. If manufactures and services are measured in constant prices, their value-added shares of GDP have remained roughly unchanged since 1970.[2]

(2) Manufacturing conducts 80% of all industrial R&D, and 60% of total R&D. R&D is the strongest single predictor of Gross Domestic Product (GDP) growth, accounting for about one-half of per capita growth in GDP.[3]

Manufacturing innovation drives innovation and growth in the other sectors – including the service sector. Within the manufacturing sector itself, research and development (R&D) activities appear to be particularly important for producing these innovation benefits. This is because manufacturing R&D drives the productivity of firms that routinely engage in it; generates and supports high-wage, high-impact jobs; advances and spawns innovation within local and regional economies; and increases the competitiveness of regional economies, enhancing their attractiveness as places to locate, relocate, or expand.

(3) The service sector in particular benefits from R&D performed by Virginia's manufacturing industries.[4]

Service industries achieve productivity gains primarily by investing in the technologically sophisticated machinery, equipment, and other tools created by the manufacturing sector.[5] The dependence of the service sector on manufacturing R&D throws a new light on recent claims that the U.S. is transitioning from a production to a service economy. Services, it appears, cannot advance without manufacturing.

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[1] Rowthorn and Ramaswamy. *Deindustrialization: Its Causes and Implications.* Economic Issues Paper # 10. Washington, D.C: International Monetary Fund. www.imf.org/external/pubs/ft/issues10/index.htm.
[2] Ibid.
[3] Office of Economic Advisers (1995).
[4] Papaconstantinou et al., (1996).
[5] Sakurai et al., (1996).

(4) Manufacturing R&D is crucial to realizing the full potential of technological innovations.

In order for a given technology to have its full economic effect, a firm must not only invent it, but also develop applications and commercialize it.[6] By inventing a new product, a firm may *establish* a new market – but only through continuous refinements and improvements of the product can that firm *keep and expand* its market share.[7] The best source of these product improvements is R&D conducted close to the production line – that is, manufacturing R&D.

(5) The benefits of R&D are spread through technology diffusion – the process by which firms acquire, adapt, and apply the technological advances created in other firms and other industries.

Diffusion has a considerable economic impact, as it spreads the technological achievements of high-tech firms throughout the economy, boosting the productivity and innovative capacity of other industries and sectors. In fact, technology diffusion can account for more than half of a nation's productivity growth in a given period – exceeding even the contribution of direct R&D.[8]

(6) Manufacturing innovations are particularly conducive to technology diffusion because of the close supply linkage among many manufacturing industries.

Most of the manufacturing sector produces not consumer goods but intermediate goods, such as industrial machines and components used in other firms' and industries' production processes. If an industrial machinery firm, for example, makes an innovation that increases the reliability or flexibility of its product, all the firms that use the improved machinery immediately begin to see productivity gains on their own production lines. The productivity improvements are embedded directly into the manufactured product, creating automatic channels for the diffusion of new technology. Manufacturing R&D therefore drives much of the economic impact of technology diffusion.

B. Location Decisions

(1) It matters where R&D happens. If technology-intensive manufacturing firms within a particular industry concentrate in a geographic location,

[6] Mansfield, Edward. "Contributions of New Technology to the Economy." In Bruce L. R. Smith and Claude E. Barfield (Eds.), *Technology, R&D, and the Economy.* Washington, D.C.: Brookings Institution and American Enterprise Institute for Public Policy Research. 1996.
[7] Schacht, Wendy H. *Manufacturing, Technology, and Competitiveness.* Congressional Research Service Issue Brief 97041, January 12, 1999. www.cnie.org/nle/econ-29.html.
[8] Ibid.

technology diffusion and knowledge spillovers will be more likely to occur in that location.

These spillovers will foster greater innovation and competitive advantage among all the low technology manufacturing and services industries in the area – in fact, all the area industry will benefit. States thus have a strong interest in the concentration and performance of their high-technology manufacturing industries.

(2) Manufacturing firms and R&D facilities have different location needs and preferences.

Manufacturers still value what they have traditionally valued – proximity to customers and/or suppliers, transportation networks, low land and labor costs, access to raw materials, etc. It has always been assumed that jobs will attract workers. But because their knowledge-based workforce is their most precious commodity, R&D facilities value whatever their workers value – and that usually means quality of life factors such as strong educational systems, proximity to research universities, cultural amenities, and employment opportunities for spouses. Because of this, R&D operations like to locate where there is an ample pool of knowledge-based workers.

(3) When making location decisions, manufacturing firms with significant R&D functions serve two masters.

Manufacturers who have a significant level of R&D activity find that they have to compromise between two types of operations requirements. They tend to locate in places that are second best. They tend to select sites that are neither the single best manufacturing site nor the single best location to attract and retain scientists, engineers, and technicians. Instead, they settle on a place that is adequate for both.

C. Performance of Virginia's Technology-Intensive Manufacturing Industries, 1989 – 1998

(1) In 1998, the Commonwealth's technology-intensive manufacturing industries had total employment of 107,975 and 1,355 firms.

The highest employment levels were in motor vehicles (12,691), plastics (11,513), electronic components and accessories (10,285), cigarettes (7,773), and communications equipment (6,287). The industries with the greatest numbers of firms were: specialized industrial machinery (87), motor vehicles (86), electronic components (76), measuring and controlling devices (72), and communications equipment (66).

(2) Although Virginia's technology-intensive manufacturing industries saw a small decline in aggregate employment, they made significant gains in output and productivity.

As a subsector, Virginia's technology-intensive manufacturing industries lost 2.7 percent of the employment they had in 1989; total employment decreased from 10,981 in 1975 to 107,975 in 1998. Over the same period, however, these industries made a 15 percent increase in output – even with nearly three percent fewer workers. This productivity gain resulted in a 17.8 percent increase in output per technology-intensive manufacturing employee. At the same time, these industries have been making above-average contributions to the wealth of Virginia's communities, by paying wages that are 37 percent higher than the average for all non-retail industry.

(3) Virginia has outperformed the U.S. in technology-intensive manufacturing employment and productivity.

For the 1989 – 1998 period, technology-intensive manufacturing in Virginia lost fewer jobs (2.7%) than did national technology-intensive manufacturing (5%). Virginia also made greater output and productivity gains than the nation did: while the national output of technology-intensive manufacturing rose by 12.7%, Virginia's output in these industries rose by 15%.

(4) Changes in the technology-intensive manufacturing subsector are not uniform across industries – there were some big winners and some big losers.

Several industries made big employment gains in Virginia. The top gainers were: motor vehicles and equipment (+4,704, 59%), miscellaneous electrical equipment (+3,183, 242%), electronic components (+2,718, 36%), special industry machinery (+1,584, 75%) and search and navigation equipment (+1,532, 83%). The top employment losers were communications equipment (-7,104, 53%), plastics and synthetics (-6,892, 37%), miscellaneous chemical products (-4,036, 64%), and cigarettes (-4,034, 34%).

All of these top employment losers, however, made significant gains in productivity and value-added per worker. In Virginia, these industries gained from 27 percent to 45 percent in value-added per worker, and from 44 percent to 92 percent in output per worker. These gains underscore the point that employment decline does not necessarily mean industry decline.

(5) Technology-intensive manufacturing is not heavily concentrated in Virginia.

Virginia has a smaller portion of its workforce engaged in technology-intensive manufacturing than does the country as a whole; in the aggregate, these industries are less than two-thirds as concentrated in Virginia as they are nationally. A few individual industries show above-average concentration in employment or number of firms, and two industries have made significant gains in concentration: guided missiles and space vehicles, and engines and turbines. Only one of Virginia's technology-intensive manufacturing industries is concentrated in *both* employment and establishments: cigarettes. Virginia thus cannot be said to have a regional advantage in technology-intensive manufacturing – but is in a good position to work toward developing that advantage.

D. Survey Results

Firm Characteristics and R&D Activities

(1) Most of the survey respondents have out-of-state locations.

About 75 percent of respondents have facilities outside of Virginia. Most of these (63% of respondents) are themselves subsidiaries or branch plants of larger corporations that are headquartered outside Virginia.

(2) The majority of the respondents have small R&D operations.

About one half of the respondents reported annual R&D expenditures of less than $250,000, 26 percent reported R&D expenditures in the $1-$5 million a year range, and about 8 percent of the respondents reported annual R&D expenditures of more than $5 million.

(3) R&D activity was most likely to increase than decrease.

A slight majority of firms experienced no significant changes in R&D employment or R&D effort (R&D expenditures as a percentage of sales) over the last ten years. More than a quarter of the firms had a major increase in R&D employment, and a third saw a major increase in R&D effort.

(4) A surprisingly high percentage of firms perform basic research.

The vast majority of firms indicated they perform applied research (84%) and engage in development activities (88%). However, 40 percent of the respondents also indicated they perform some basic research. The latter firms indicated that basic research typically represents from 5 to 20 percent of their research activities.

(5) The majority of firms attach R&D functions to specific production functions.

Sixty percent of the respondents concentrate their R&D activities in a single location. They also, however, tend to attach their R&D functions to specific product or process areas (59%), rather than maintain a centralized core group that worked across product and process areas.

(6) The majority of firms collaborate on research activities.

Sixty percent of the respondents indicated some form of collaboration with universities, federal labs, other companies, or other research facilities. Over half of those that have collaborative activities with external parties have research relationships with at least one out-of-state organization.

(7) General characteristics of the firms surveyed:

- About half the respondents had annual sales in excess of $50 million and about 30 percent had annual sales of more than $100 million.

- The firms reported having nearly 43,000 permanent, full-time employees at their Virginia locations with 3,088 (7.2%) working in R&D and 27,045 (62.9%) in manufacturing/ production.

Changes in R&D Performance

(1) The majority of respondents see government programs as a significant influence on their firm's R&D activities.

Almost 80 percent of the respondents indicated that one or more government programs were a major influence on their ability to maintain or increase their R&D presence. The public programs that were most frequently cited as "critical" to current R&D activities were R&D investment tax credits (30% of the respondents) and assistance from Virginia's Center for Innovative Technology (22%). The most frequently mentioned areas in which the respondents felt government polices or incentives could have a positive impact on R&D investment were: state R&D tax credits and access to state and federal R&D grants.

(2) Respondents expanded R&D activity in response to competitive pressures, industry growth, and availability of skilled workers.

For firms that significantly expanded their Virginia-based R&D activities over the last ten years, two factors were by far the most important. They were "competitive pressures to innovate" and "growth within their specific industry," with nearly 90 percent of firms citing these factors as extremely or very important.

"Availability of skilled workers" was the third most frequently-cited factor, with 54 percent of the respondents indicating it was extremely important or very important. Given that the majority of respondents attached their R&D functions to specific product or process areas, this finding suggests the possibility that an adequate supply of skilled production workers is a necessary condition for these firms to consider expanding R&D investment or employment.

Only 11 percent of firms that increased R&D activity rated relationships with universities as very important – even though, as previously mentioned, 40 percent of the respondents indicated they engaged in basic research.

(3) Respondents decreased R&D activity in response to financial difficulties and industry slowdowns.

For firms that significantly decreased their Virginia-based R&D activities over the last ten years, two factors were by far the most important. They were "financial conditions within the company" (86%) and "slowdowns within their specific industry" (64%).

Only 36 percent of the firms that significantly decreased their Virginia-based R&D activities over the last ten years considered "lack of skilled workers" to be a very important or extremely important influence on their decision. This finding suggests that for those responding, an adequate supply of skilled workers played a larger role in decisions to expand R&D operations than in decisions to contract operations.

Location Factors

(1) Traditional manufacturing considerations, particularly workforce needs, played a greater role in location decisions than did R&D considerations.

The most frequently-cited extremely or very important location factors (those above the 41% median) emphasized production needs. Four location factors, three of them workforce-related, were cited by about 70 percent of the respondents as being extremely or very important. The factors are labor productivity, business environment, availability of a skilled workforce, and labor costs. Also above the median were two other production-related factors: regulatory environment and transportation.

(2) Some respondents also stressed factors typically of concern to R&D facilities.

Several R&D-related considerations were also above the median, including quality of K-12 education, availability of technicians, availability of scientists and engineers, and availability of managerial employees.

Other R&D-related factors, including proximity to universities, cultural amenities, and research facilities, were all ranked toward the bottom of the list. Only 15 percent of the respondents indicated proximity to universities was very important or extremely important as a location factor, and 9 percent indicated proximity to research facilities was very important. This finding, when coupled with the finding that 60 percent of the responding firms had collaborative research relationships with outside parties, suggests the possibility that distance from research partners is not a significant impediment nor is proximity a significant advantage for these respondents.

E. Policy Recommendations

The research findings and conclusions suggest four areas for further consideration by the Commonwealth of Virginia as potential effective policy actions.

(1) Separate Statewide Strategy

- **Consider crafting and implementing a separate and distinctive statewide development strategy to advance the competitiveness of the technology-intensive manufacturing community and to foster public awareness of its critical role within Virginia economy.** The vitality of Virginia's technology-intensive manufacturing community will have a major impact on the economy's capacity to generate better jobs, higher incomes, and more wealth in the Commonwealth's communities.

- **Explore the feasibility of implementing a focused workforce development strategy for technology-intensive manufacturing companies (with R&D activities**). Skilled workforce availability was reported as a major factor in location decisions and in R&D expansion decisions. Availability of technicians, scientists and engineers and managerial employees were also reported as influential factors but to lesser degrees. Any strategy designed to address these factors should be based on an in-depth analysis of this group's workforce needs and issues. For instance, do the firms within the technology-intensive manufacturing community face common or generic workforce issues or do they tend to be industry or cluster-specific? Do needs vary according to firm size or from region to region within the state?

(2) Encouraging Private Sector R&D

- **Investigate the economic development efficacy of establishing more aggressive R&D tax credits customized to motivate and support R&D expansions for technology-intensive manufacturers.** The respondents regarded R&D tax credits as the single most important government-related action that could affect their future R&D investments.

- **Consider establishing a single gateway for technology-intensive manufacturers to obtain clear, simple information and gain access to federal and state government resources that can advance their R&D objectives.** Such a gateway might best be marketed and managed at the regional level. Almost 80 percent of the respondents indicated that one or more government programs were a major influence on their ability to maintain or increase their R&D presence.

(3) Recruitment and Retention

- **Focus on retaining, supporting, and recruiting technology-intensive manufacturers as a strategy to boost R&D employment and investment.** The survey findings suggest that technology-intensive manufacturers with significant R&D activities will concentrate first on satisfying their manufacturing requirements. The R&D-related factors that effect expansion or location are still important, but they are not the first priority. To the extent this is true, R&D employment and investment gains may well be realized by addressing these firms' manufacturing-related needs and issues. This seems logical since well over half the respondents reported that their R&D functions were attached to specific product or process areas.

- **Local and state economic development personnel could consider establishing on-going support efforts for Virginia-based sites' bids and proposals within their respective corporate decision-making environment.** It matters where R&D happens. Well over half the respondents indicated they were subsidiaries or branch plants and 73% reported they had out-of-state facilities. This may be especially important for older technology-intensive manufacturing facilities as they make pitches to corporate headquarters for new production lines or manufacturing or process technology changeovers. Based on close and trusted working relationships with local management, this support could take such forms as workforce training, improving transportation access, commitments to recruit important suppliers, or demonstrations of wide-spread community backing.

(4) Strategic Partnerships

- **Compile more detailed information and analysis on the external research plans and needs of private manufacturing R&D performers.** A surprising 40 percent of the respondents indicated they were engaged in basic research, but only 11 percent rated relationships with universities as very important. There may be some fruitful opportunities to build stronger research relationships between the technology-intensive manufacturing community and the states' universities; however, more information is needed.

- **Explore the desirability of supporting R&D alliances and networks among its technology-intensive manufacturers.** R&D alliances can be very effective ways to extend and augment firms' capabilities, development strategies, and budgets. This is especially true for smaller R&D operations (over half of the respondents had R&D budgets of less than $250,000). The productive formation of R&D alliances is more feasible where the participants are accustomed to collaborative endeavors. The majority of the respondents (60%) indicated that they collaborate with universities, federal labs, other companies, or other research facilities; over half of those who collaborate have out-of-state partners.