Environment and Planning C - Government and Policy
Volume 14, 431-450, 1996

New Technology Adoption in West Virginia: Implications for Manufacturing Modernization Policies

by

Philip Shapira* †
and
Terance Rephann**

*Associate Professor
School of Public Policy
Georgia Institute of Technology
Atlanta, GA 30332-0345, USA
e-mail:ps25@prism.gatech.edu

*Research Associate
Regional Research Institute
West Virginia University, PO Box 6825
Morgantown, WV 26506-6825, USA
e-mail: u24c1@wvnvm.wvnet.edu

†Corresponding author

Acknowledgments

This research was supported by the West Virginia Institute of Technology EDA University Center (from funds received through the Economic Development Administration, U.S. Department of Commerce), the West Virginia Development Office, the Robert C. Byrd Institute for Advanced Flexible Manufacturing Systems, and the West Virginia University Industrial Extension Service. Andrew Isserman, Robert Lehman, David Greenstreet, Edward Malecki, and Hal Wolman provided very helpful comments.

**New Technology Adoption in West Virginia:
Implications for Manufacturing Modernization Policies**

Abstract

This paper explores the determinants of new technology adoption using data obtained from a 1993 survey of 299 manufacturing establishments in the state of West Virginia. It examines the use of 20 hardware-based and organizational new manufacturing technologies, aggregate technology use, and plans for future technology use. Multivariate regression analyses indicate that larger, export-oriented, branch plants that manufacture products in long production runs and plants that are located in counties with a sizeable manufacturing sector adopt more new technologies than other types of plants. The results also suggest that there is a role for further government policy in encouraging plant modernization. Although participation in a state technology assistance program is not yet associated with higher levels of aggregate new technology use, it is found to associated with adoption of specific technologies and receptivity to new technology investment. The study's results also confirm the value of training and suggest that a strategy of targeting smaller and medium-sized plants with services focused on multiple clustered locations may be effective in stimulating new technology use among these manufacturers.

1. Introduction

Over the past decade, a shift has occurred in the ways that state governments in the United States approach economic development. The old approach, derived from supply side theories of regional growth, suggested that states could foster development by decreasing the relative cost of labor, capital, land and other resources, thereby improving prospects for the attraction of new branch plants. In practice, this often meant subsidized loans, tax breaks, training assistance for new employees of incoming factories, building physical infrastructure, and other policies designed to make investments cheaper for large firms. Although still used, these policies have been complemented by an increased emphasis on indigenous economic development (Eisinger, 1988). A central element of this strategy is to boost area small and medium-sized businesses through better access to financing, management and marketing support, training, and incubation assistance. Parallel changes in the behavior of state and local institutions are sought to encourage a supportive environment for entrepreneurship (Osborne and Gaebler, 1992). Increased attention is also devoted to innovation, with states promoting research, high technology business start-ups, and technology transfer (Berglund and Coburn, 1995).

Linked with these new state developmental approaches has been a growing movement to stimulate manufacturing modernization (Rosenfeld, 1992; Shapira, Roessner and Barke, 1995). Manufacturing modernization strategies seek to upgrade small industrial firms' performance and capabilities to produce competitive, high quality products through improved technology, training, design, marketing, management, and business relationships. Through these means, it is hoped that small indigenous firms can better respond to increased global competition and retain, if not expand, high-wage industrial employment. The idea has been around in one form or another for several decades. For example, the Georgia Institute of Technology's industrial extension service has deployed field engineers to provide technological assistance to local firms since the late 1950s (Clifton et. al., 1989). However, only over the past few years has manufacturing modernization become a widespread objective of state economic development policy (Shapira, 1990). Extensive federal support for state manufacturing modernization efforts is even more recent—with major funding now flowing through such new national programs as the Technology Reinvestment Project and the Manufacturing Extension Partnership (Advanced Research Projects Agency, 1993; National Institute of Standards and Technology, 1995).

As support for manufacturing modernization programs has grown, varied information and analytical techniques have been used to characterize how industrial firms currently use new technologies and the need for—and likely impact of—new program initiatives (Youtie, Shapira and Roessner 1995). For example, in the application procedure for the manufacturing extension element of the federal Technology Reinvestment Project, states and other proposers had to do little more than identify, in descriptive terms, the number of manufacturers within their boundaries and the proportion who were dependent on defense sales (Advanced Research Projects Agency, 1993). The implied assumption was that across the universe of firms within a proposing area there were unmet needs for program assistance for technology adoption and, among defense suppliers, for conversion assistance to access civilian markets. In other cases, the approach has been more systematic, using surveys to assess technology adoption and company needs (Industrial Technology Institute 1987; Ostrowiecki, et. al, 1992; North Carolina Alliance for Competitive Technologies 1995). However, such surveys by themselves may miss the subtle links between a plant's use of modern technology and a variety of local economic, industrial, spatial, and other determinants. Comparing company, sector or state averages without taking into account these sources of underlying variation can create an incomplete picture of regional technology capabilities. The need to account for local conditions also arises in those instances where states—in designing new manufacturing modernization initiatives—have modeled their programs on ones already operating elsewhere. While it is reasonable to draw on the experience of other places in developing modernization programs, care needs to be taken in ensuring that modernization policies for individual areas are tailored to the actual needs and circumstances of that location. This is especially true in rural areas which may lack a host of characteristics favorable to the development and diffusion of modern technologies.

To better understand the particular determinants and characteristics which affect modernization efforts in specific areas, we suggest that a multivariate analysis framework is helpful. Drawing on an industry survey conducted in the state of West Virginia, we identify several of the underlying sources of plant variation in technological adoption. This information is used to understand the factors that should be accounted for when developing modernization objectives and benchmarks, suggest categories of manufacturers that would be the most appropriate for targeting technology assistance, and assess the likely effects of policies that have been promoted for encouraging manufacturing technology adoption. The text is divided into several sections. The next section summarizes existing explanations for variation among manufacturers in technology use, identifies factors frequently found to be important, and highlights areas of debate and policy concern. Section 3 provides the regional context for the study and outlines the survey design. Section 4 presents a multivariate regression framework to assess the effect of different plant, industry, and regional factors. It reports the results of regression analyses for aggregate new technology use, the decision to adopt individual technologies, and plans to adopt new technologies. Section 5 examines the policy ramifications of the empirical results. It considers how state policy can be used to facilitate plant modernization and how industrial extension services might best be targeted . Section 6 is a summary and conclusion.

2. Determinants of New Technology Adoption

Numerous theories have been put forward to interpret patterns of new technology adoption. The technology adoption elements highlighted by these theories include: the role of information and time; the cost-performance of technology relative to other production factors; individual firm characteristics such as size, age, or ownership; managerial and labor qualities; industry, product and market factors; inter-firm linkages and relationships; spatial agglomeration and proximity; aggregate business and economic conditions; and the institutional and policy environment (Carter and Williams, 1957; Rogers, 1962; Utterback, 1974; Davies, 1979; Mansfield, et. al, 1977; Stoneman, 1983; Dosi et. al, 1988; Sweeney, 1987; Tornatzky et. al., 1990).

A series of empirical studies have sought to operationalize and measure the importance and direction of these various elements. These studies have not always been conclusive and in agreement, but the weight of evidence to date suggests that new industrial technology adopters can be characterized by several features. They are generally larger companies with relatively better trained workers who, in turn, are more likely to be higher paid and unionized (Mansfield, 1963; Romeo, 1975; Brown, 1981; Benvignati, 1982; Besant, 1982; Rees et al., 1984; Hicks, 1986; Wozniak, 1987; Gillies and Kruzich, 1988; Davelaar and Nijkamp, 1989; Kraft, 1989; Alderman and Davies, 1990; Braga and Willmore, 1991; Britton, 1991; Kelley and Brooks, 1988, 1991; LeBrasseur and Nasierowski, 1991; Alderman and Fischer, 1992; Jang and Norsworthy, 1992; MacPherson, 1992; Appold and Gant, 1993; Young et al., 1993). They are more likely to be branch plants and have innovative, younger, and better educated corporate and plant management (Mansfield, 1963; Romeo, 1975; Globerman, 1975; Rees et al., 1984; Hicks, 1986; Jaikumar, 1986; Kraft, 1989; Braga and Willmore, 1991; Britton, 1991; Tödtling, 1991; MacPherson, 1992; Jang and Norsworthy, 1992; Variyam and Kraybill, 1993).

They are more active in promoting internal and external informational sources for new technology and development (Globerman, 1975; Romeo, 1975; Rees et al., 1984; Davelaar and Nijkamp, 1989; Britton, 1991; Kelley and Brooks, 1988, 1991; MacPherson, 1988, 1992; Tödtling, 1991). This includes greater reliance on assistance from customers, suppliers, and other firms within the industry (MacPherson, 1988, 1992; Young et al., 1993; Kelley and Brooks, 1991). In addition, they are more likely to employ other new technologies and be drawn disproportionately from newer plants (Besant, 1982; Rees et al., 1984; Hicks, 1986; Jang and Norsworthy, 1992; MacPherson, 1992; Appold and Gant, 1993).

In addition, if not defense contractors, technology adopters are more likely to be found where customers are demanding and supportive (Kraft, 1989; Davelaar and Nijkamp, 1989; US Department of Commerce, 1989; Braga and Willmore, 1991; Jang and Norsworthy, 1992; MacPherson, 1992). Technology adopters are also more likely to be prevalent in urban agglomerations and other locations where positive industrial, information and technological externalities exist (Rees et al., 1984; Brugger and Stuckey, 1987; Dieperink and Nijkamp, 1988; Kraft, 1989; Davelaar and Nijkamp, 1989; Antonelli, 1990; Britton, 1991; Tödtling, 1991; Oakey and O'Farrell, 1992; Rosenfeld, 1992; Tödtling, 1992; Appold and Gant, 1993).

However, on other attributes there is less consensus. For example, no simple significant relationship seems to exist between technology adoption and plant sales or employment growth (Mansfield, 1963; Davelaar and Nijkamp, 1989; Braga and Willmore, 1991; MacPherson, 1992). More fundamentally, changes in business, technological, and policy environments have stimulated fresh argument about the factors favoring technological adoption and the impact of new policy interventions. Thus, despite the disproportionate influence past studies have ascribed to urban agglomeration, recent success stories among semi-rural regions in Denmark, Northern Italy, and Japan have pointed to a broader constellation of regional social, economic, and institutional variables that may affect technological adoption behavior (Friedman, 1988; Hansen, 1991; Storper, 1993). It has also been argued that global transformations in markets, technology, business, and society have diminished the advantages of size, making it easier than previously for smaller firms to develop and adopt flexible new technologies and successfully compete against larger firms (Piore and Sabel 1984; Gilder, 1989; Sengenberger, 1990). Finally, there has been increased debate (particularly in the United States) about the effectiveness of public policies to promote the deployment of new technology. While there is some evidence that public policies can stimulate firm innovation and improve business practices, concerns remain about the impact of these programs and whether public spending on them is justified (Shapira, Youtie and Roessner 1996).

Our study and analysis of technology deployment in West Virginia draws upon and seeks to inform this body of literature and debate in three ways: first, to confirm whether key influences on technology adoption found in earlier studies still continue to be significant; second, to provide new empirical evidence which can contribute to current debates about the role of place, proximity and size in technology adoption; and, third, to develop preliminary information about the effect of new public policies to stimulate industrial modernization.

3. Context of Study and Survey Design

West Virginia—with a population of about 1.8 million—contains about 2,000 industrial establishments. In 1990, manufacturing contributed 17 percent of the state's economic output (compared with 19 percent for the nation).[1] The state's manufacturing sector is most specialized in heavy and resource-intensive industries, such as chemicals, stone, glass, and clay, primary metals, lumber and wood products, and leather products, and is underrepresented in "high tech" industries, such as machinery, computer equipment, and electronic equipment (although there are some firms in the state producing in these sectors).

The industrial economy of West Virginia forms part of the older Northeast and Great Lakes industrial region (e.g., Ohio, Michigan, Pennsylvania, and New York) rather than the new southern industrial region (e.g., Kentucky, Virginia, Tennessee, North Carolina, South Carolina, and Georgia). In 1993, West Virginia had about 83,000 manufacturing employees (13 percent of all nonagricultural employment). As in other Northeast and Great Lakes states, manufacturing jobs in West Virginia have declined in recent years. Indeed, during the past two decades, West Virginia manufacturing employment declined faster than all but three states in the United States, falling approximately 35 percent over the period 1969-91 (compared to a drop of 7.5 percent for the nation as a whole). West Virginia's manufacturing job losses were broad-based, but particularly harsh in high-wage heavy industry sectors. The losses were also concentrated regionally, affecting the industrialized metropolitan areas more severely than the more rural sections (there are five small to mid-sized metro areas in the state). While some manufacturers added jobs in the 1980s and 1990s, these were concentrated in lower wage industries such as wood products and in sparsely populated eastern counties. The additional jobs were not enough to offset the much larger manufacturing employment losses elsewhere in the state.

West Virginia's state government has reacted to the erosion of its manufacturing industrial base in multiple ways. Like other states, it has pursued traditional industrial recruitment strategies to try to attract new manufacturing plants. New service-sector activities, such as tourism, have also been promoted. Increasingly, however, the state is turning towards policies to aid existing local manufacturers in responding to heightened international competition, rapid technological change, and pressures for improved quality. Several new technology and training initiatives have been launched in recent years. The Governor's Guaranteed Work Force Program offers one-stop access to help state firms train and upgrade their employees. A Flexible Manufacturing Network Team of state-wide technology service providers has been formed to promote collaborative industrial modernization efforts among small and medium-sized firms. A major new initiative, created in 1991, is the West Virginia University Industrial Extension Service (WVU-IES). It employs field engineers in regional offices around the state who work one-on-one and cooperatively with manufacturers to identify production problems, recommend modernization approaches, and provide technology assistance.

West Virginia's state efforts have been augmented by support from federal agencies and other regional organizations. With federal, state, and private sponsorship, the Robert C. Byrd Institute for Advanced Flexible Manufacturing Systems at Huntington's Marshall University provides training, demonstration facilities, and technical assistance in new technologies. The Consortium for Manufacturing Competitiveness consists of a network of engineers and technology demonstration centers based at 14 community colleges throughout the South, including a branch at West Virginia University at Parkersburg. Other externally sponsored technology outreach programs that are assisting state manufacturers include the National Technology Transfer Center located at Wheeling Jesuit College in the northern West Virginia panhandle; the NASA Technical Application Center in Pittsburgh, Pennsylvania; and two centers that target the wood industry, the Appalachian Hardwood Center located at West Virginia University and the Advanced Hardwood Processing and Technical Resource Center located in Princeton, West Virginia. In 1995, federal funding from the National Institute of Standards and Technology’s Manufacturing Extension Partnership, matched by the state, led to the founding of the West Virginia Partnership for Industrial Modernization. Involving WVU-IES and the Byrd Institute, this will expand the number of industrial extension agents in the state and support the coordination of modernization services.

To provide information about the extent of new technology adoption, the factors which affect it, and the relationship of state manufacturers to new technology assistance services, a survey was conducted during

1993. The survey was directed to all identifiable plants employing 10 or more people in the major industrial sectors of textiles and apparel, lumber and wood products, furniture and fixtures, paper, chemicals and allied products, rubber and plastics, glass, primary and fabricated metals, non-electrical machinery, electrical machinery and electronics, transportation equipment, instruments, and miscellaneous manufacturing. Also included were selected miscellaneous industrial repair shops and services.[2] The establishments included in these categories were those primarily targeted for assistance by WVU-IES. By focusing on this group of industries, it was possible to identify a broadly applicable set of new technology applications and also obtain information on sectors comprising a substantial portion of the state's manufacturing output and employment.

The questionnaire used in the survey asked manufacturers about their use of new technologies, future technology plans, sources for technology information and assistance, training, networking, and research and development activities, and technology assistance needs. Questionnaires were mailed to 929 plants. After mail and telephone follow-up, 299 were returned with sufficient detail to permit them to be tabulated. After accounting for misclassified, relocated, and defunct plants, the overall survey response rate was 37.1 percent, a relatively high rate when compared to similar industry surveys. The survey base sample was stratified by industry and establishment size and in analyzing the survey results, the reported data is weighted using an expansion weight equivalent to the reciprocal of the selection probability for each cell in the stratified sample.

The analysis in this paper focuses on responses to questions dealing with adoption and future plans for 14 hardware based (i.e., "hard) and 6 organizational (i.e., "soft") technologies. The "hard" technologies probed by the survey perform several functions in the manufacturing processes. Shop-floor computers, flexible manufacturing systems (FMS), and computer integrated manufacturing (CIM) are used to link and control manufacturing equipment and processes. Computer-aided design (CAD) and computer-aided engineering (CAE) are used for designing and, increasingly, to provide computable instructions for programmable shop-floor tools and production processes. Numerical control (NC), computer numerical control (CNC), and lasers are used primarily in machines that cut or shape materials. Sensors and data collection devices detect production movements, measure materials and quality, and record inventory information. Robots are used primarily to move and assemble components. Automated material handling systems are used to transport and store materials. The "soft" technologies examined by the survey were statistical process control (SPC), just-in-time delivery systems (JIT), employee involvement programs (EIP), and Total Quality Management

(TQM). These techniques are used to improve quality, reduce scrap and inventories, and improve labor participation and efficiency. The survey found that the current adoption rates for both "hard" and "soft" technologies varied widely, with the highest levels found for personal computers used off the shop floor and for production, planning, and inventory control software and the lowest levels for flexible manufacturing systems and robotics (Table 1). A full description of the survey and tabulated responses to other questions can be found in Rephann and Shapira (1994).[3]

4. Multivariate Analysis of Technology Adoption

4.1 Model Design

To systematically examine the contribution made by the variables identified in the literature review to plant technology adoption levels and to better understand the determinants of plant technology use, a weighted multivariate regression analyses was conducted. The dependent variable was aggregate new technology use (TECHUSE)—a count of the number of specific hard and soft technologies adopted by the plant (see Table 1 for a list of the technologies). This plant technology adoption index was selected after experimenting with several alternatives.[4]

The independent variables, shown in Table 1 with their names and hypothesized coefficient signs, were divided into categories representing plant-level, industry, regional, and policy influences. Plant-level variables were represented by employment size (EMPLOY), prior job growth (GROW), age of plant (AGE), organizational status (BRANCH), employee unionization (UNION), employee training (TRAIN), and whether the plant had capabilities to conduct manufacturing process engineering (MFGPROC). The variables BRANCH and MFGPROC were expected to have positive relationships with technology adoption because they measure access to internal organizational and technical resources. TRAIN was also expected to have a positive relationship since upgraded workforce skills should make it easier for firms to introduce, use, and further enhance in-plant technologies. EMPLOY should have a positive coefficient because of scale effects for new technology adoption described earlier. UNION, GROW, YEAR had uncertain signs. UNION could conceivably cause both higher or lower technology adoption depending on the extent of substitution or disinvestment influences. GROW should have a positive coefficient if it represented plant dynamism but would have a negative sign if new technology-labor substitution was occurring. YEAR would have an indeterminate sign if both older and younger plants were higher adopters because of vintage capital effects.

Industry features were represented by variables describing the manufacturing process employed (CUSTOM, BATCH, VOLUME, SMPROC, LGPROC, REMAN), market characteristics (EXPORT and DEFENSE EXPORT), and industry relationships (CUSTAID, LINKS). The manufacturing process variables were used in lieu of categories defined by Standard Industrial Classification (SIC) codes because they explained more technology use variation in preliminary runs and because previous studies had found that SIC codes offered little insight into plant technology adoption decisions (Brugger and Stuckey, 1987; Davelaar and Nijkamp, 1989; Young et. al., 1993). Plants with industrial lines making products in long runs (VOLUME), making products in batch runs (BATCH) or processing materials in large volumes were expected to have a positive relationship with the adoption of new manufacturing technologies, attributed to the effects of scale on technology adoption. But, an indeterminate sign was expected for plants with industrial lines engaged in customized production (CUSTOM), re-manufacturing and repair (REMAN), and material processing in small volumes (SMPROC). Traditionally, variability in product or process demands in these industrial lines has made it hard to use standardized technologies (thus leading to a negative relationship). However, it was also possible that the new economies of scope and improved flexibility embodied in recent technologies might now be increasing adoption rates (causing a positive correlation). EXPORT and DEFENSE markets were hypothesized to be more demanding customers. Therefore, each should have a positive effect on technology adoption levels. Assistance from customers (CUSTAID) and participation in inter-company groups and networks (LINKS) were expected to have a positive relationship, since these offered enhanced access to external information, technical resources, and stimulation.

Several regional indicators were used. Indicators of the influence of agglomeration and proximity were provided by ADJCODE (which measured the relationship of a given plant location to metropolitan areas) and MFG (which measured total manufacturing employment in the plant's county). The remaining variables measured transportation linkages (HWY), labor force quality and educational infrastructure (EDHIGH and COLLEGE), and overall economic conditions in the plant's county (RMFG and RTOT). Each of the regional variables were expected to have positive relationships with new technology adoption, with the exception of ADJCODE which was expected to have a negative sign (i.e. the more rural the location, the less likely to adopt technology). TECHAID is a public policy variable that indicates whether or not a plant received technology assistance from the primary technology transfer agency in the state, the West Virginia University Industrial Extension Service.

4.2 Current Technology Adoption: Results

Table 2 reports the results of the analysis. It shows that technology adoption was associated with employment size (EMPLOY), ownership status (BRANCH), formal training (TRAIN), and three industry characteristics (VOLUME, REMAN, and EXPORT). These had positive signs and were statistically significant. External assistance variables (i.e., LINKS, CUSTAID, and TECHAID) had positive coefficients, but they were not statistically significant. These findings on the importance of plant employment size and branch plant status did not give support to the view that small independent firms are by themselves able to deploy new technology to the same extent as large corporate units. The only regional indicator which was statistically significant and had the expected sign was local manufacturing employment (MFG). This is consistent with the view that regional concentrations of manufacturing establishments promote the diffusion of new technologies, although the size of the effect observed in the study was relatively small. There was no statistically significant relationship with local high school completion, county higher education student enrollment, or the presence of interstate highways. This result did not change appreciably when the plants were stratified by plant size and organizational status. Thus, technology adoption among smaller and independent plants was not noticeably more sensitive to regional educational and infrastructure characteristics than found in large units and branches.

Our aggregated analysis of technology use was supplemented by an examination of the factors associated with the adoption of individual technologies. The extended 25 variable equation was used again in weighted regressions for the individual technologies, where "0" meant that a plant had not adopted the particular new technology and "1" meant that it had. Table 3 reports the results of probit regressions for each technology (except robotics, which was not deployed in any of the 202 plants included in this regression analysis). It reveals that the factors associated with new technology adoption differ somewhat according to the particular technology.

Employment scale was the most pervasive plant-level influence of new technology adoption. It was positively and significantly associated with the adoption of 9 of the 19 technologies (shop-floor computers, control devices, sensors, computer-aided engineering, flexible manufacturing systems, computer integrated manufacturing, production, planning, and inventory control software, Total Quality Management, and inter-company computer networks). Formal training programs were positively and statistically associated with one "hard" technology (shop-floor computers) and three "soft" technologies (just-in-time, employee involvement programs, and Total Quality Management). This latter finding hints at a link between training and the deployment of new organizational and work-place technologies requiring greater levels of scheduling, participation and group effort. Branch plants were more likely to adopt only three new technologies: inter-company computer networking, sensors, and lasers. This result indicated that employment size offered a better explanation of new technology adoption than plant ownership status. Plant export-orientation was related to five new technologies, including ones connected to quality assurance such as statistical process control, just-in-time production, and employee involvement programs. However, defense sales were significantly associated with only one new technology (numerical control) and there was no significant relationship between defense sales and the use of organizational or quality improvement techniques.

Variables that were not statistically significant on the aggregate level sometimes exhibited positive effects on the likelihood of adopting specific new technologies. For example, plant unionization showed a positive relationship with the adoption of numerical control, computer-aided design, computer-aided engineering, statistical process control, and off-the-shop-floor personal computers. This finding is interesting because it may indicate a subtle shift of control from shop-floor personnel using manual procedures (such as reading blue-prints and then setting-up machines) to off-the-floor technical workers using computerized techniques. Even within unionized plants, off-the-floor technical workers are less likely to be unionized. Customer assistance was noticeably associated with the adoption of organizational technologies such as statistical process control, just-in-time, and employee involvement programs. These methods are directly related to quality improvements, timeliness, and problem solving and may be stimulated by contractual or competitive requirements to maintain business with key customers. Technical assistance from the industrial extension service also influenced technology adoption, mainly for "hard" technologies (in contrast to customer assistance). Those plants that had received assistance from WVU-IES were more likely to be adopters of computer-aided design and engineering, lasers, and computer-integrated manufacturing.

As expected, particular production processes played an important part in technology adoption choices. For instance, plants with long production runs were associated with a greater likelihood of adopting automated handling systems and computer integrated manufacturing (CIM). While production in volume might be expected to benefit from line and handling automation, the result for CIM is an interesting one. In concept, the flexibility of such systems should benefit plants with more varied products lines. Possibly the mass producers in the survey were using CIM to improve quality and productivity under conditions of volume production, rather than to increase customization. Indeed, we found that customized production was negatively associated with many hardware-based new technologies. Despite the promise of improvements in flexibility, responsiveness and scope economies assigned to these new technologies, we did not find a significant take-up by customized producers in West Virginia. We did find that batch production was associated with the adoption of numerical control and computerized numerical control machines, but this production category was not distinguished by as great an adoption of integrated or flexible arrangements as might have been anticipated. This result can be reconciled with the finding of Kelley and Brooks (1988) that programmable automation is more prevalent among batch processors producing diversified production lines. Unless production design requirements change between production runs, CIM and FMS are unlikely to be needed.

Regional level factors were significant in only a few technology choices and did not show consistent patterns. There was no discernible regional difference in the use of personal computers—the most generalizable technology. This confirms—albeit rather weakly—the somewhat circular spatial diffusion hypothesis that regional factors will be less important for technologies with high diffusion levels. Organizational technologies, such as employee involvement and total quality management, are more likely to be adopted in counties with higher levels of manufacturing activity. In these counties, it is possible that the greater concentration of firms has stimulated the spread of these techniques. This evidence on regional factors should be regarded tentatively. Because West Virginia is a relatively small state, internal geographical characteristics may not play as significant a role in plant technology adoption behavior as might be found in studies of larger and more differentiated regions.

4.3 Future Plans and Needs

When states target technology assistance, it is clearly useful to understand what types of plants are inclined to modernize in the future. In some instances plants may be considering adopting new technologies but need additional assistance to follow through on their plans. On the other hand, plants which are unlikely to modernize are not good candidates for outreach efforts. They may not have the motivation, resources, or managerial acumen to implement recommendations made by outside consultants. In between are plants that may not currently have plans for technology adoption but which might be stimulated to modernize through policy intervention. In order to investigate this issue further, a second regression analysis considered manufacturers' plans to make additional technology investments. The dependent variable, drawn from our survey of manufacturers, was the number of new technologies plants planned to adopt over the next three years. The 25-variable equation was used, once again, to disentangle the influence of different plant, industry, region, and public policy variables on technology adoption. The second column in Table 2 reports the results of this analysis.

We found that the characteristics of future new technology adopters differed from current users. Employment size, ownership status, and training program presence, found to be associated with current technology adoption, were not important characteristics of planned investments. Plants planning to use new technologies were more likely to be faster growing plants (GROW), with trade unions (UNION), producing products for defense markets (DEFENSE) or performing repair or refurbishment manufacturing processes (REMAN). They were also more likely to be located near metropolitan areas (ADJCODE). A strong association was also evident with receipt of public technical assistance (TECHAID), suggesting that industrial extension services in West Virginia—still relatively new at the time of the survey—had greatest influence not so much on current technology use but on future plans to use technology.

5. Policy Implications

State and federal agencies in the United States are expanding funding for manufacturing technology assistance and this growth is likely to continue over the next few years. The results presented here have certain implications for how these activities should be designed and evaluated, as the following sections discuss.

5.1 Technology surveys and regional benchmarks

Information about technological capabilities, needs and opportunities is vital to the systematic development and implementation of manufacturing modernization policies and programs. Technology surveys can help to provide such information. They offer insights into regional manufacturing technology deployment levels, highlight gaps and needs, and—if contrasted with comparable studies elsewhere—indicate how an area's industries measure up technologically against those of other regions and countries (Rosenfeld, 1992). However, the results presented here suggest that a certain amount of caution be used in interpreting the aggregate results of technology surveys. There are invariably differences in industry structure and production which affect the applicability of particular new technologies. For example, in some rural areas, there may be a disproportionate share of resource process industries who are less likely to adopt new technologies. Similarly, localities with many small and independent manufacturers may also exhibit lower levels of new technology use. In such circumstances, technology lag is not in itself remarkable, although a widening in the gap over time or evidence that technology lag is attributable to weaknesses in management strategy, training, or industry and regional information and assistance linkages might give cause for concern. In this regard, multivariate analyses of technology surveys can be helpful in going beyond aggregate counts by highlighting and controlling for specific variables and factors.

5.2 Industrial targeting

A few studies have suggested that some plant targeting is needed to get the greatest leverage from public resources invested in technological modernization programs. For example, Simons (1993) suggests that resources be focused on 50,000 (out of 360,000) U.S. firms which "offer the highest impact on the economy." However, this approach can be criticized as a strategy of triage which suffers from a too narrow definition of economic efficiency. Taking into account the paybacks from ameliorating market failures such as externalities and information asymmetries, the case can be made that assistance should be made available in some form to all willing participants.

Yet, targeting is already practiced to some extent. Technology assistance programs typically favor small (10-99 employees) and medium-sized plants (100-500 employees). There are several reasons for this choice. First, larger plants (500+) already have the resources and technical personnel to implement modernization programs. Therefore, they are not likely to need many of the services offered by technology assistance programs. Second, very small establishments are less likely to have the capital to implement modernization projects. Even if they were able to afford the expensive hardware needed for some flexible manufacturing processes, they often lack the management and engineering skills to successfully integrate the technologies. Third, as larger firms to devolve centralized operations and subcontract some of their manufacturing previously performed in house, a substantial portion of future sales and employment growth is likely to occur in smaller and medium-sized plants.

Analysts have suggested several additional variables for industrial targeting, though they have rarely been used in practice. These variables include industry, locational factors, organizational status, and customer characteristics. Some studies of technology adoption have favored targeting assistance to industries based on their linkages with other sectors and their direct contribution to output. For example, Wiarda (1989) identifies a group of core industries, including part or all of the textile, apparel, furniture, plastic products, primary metal, fabricated metal, machinery, electronic equipment, transportation equipment, and instrument industries. However, because regions differ in industrial mix and comparative advantage, it is hard to get consensus on a single national target list. If targeting occurs, states will inevitably develop their own priority industries. Other analysts favor locating technical assistance centers and services in places where firms geographically concentrate (Fogarty and Lee, 1991. It is submitted that services located in more centralized urbanized areas can, for a given resource expenditure, reach more manufacturers. Close proximity to universities and colleges is also commonly suggested to expedite technology transfer to the private sector.

The results found here did not confirm a relationship between university or college enrollment and technology use, but they did suggest that certain categories of plants are more likely to benefit from technology assistance than others. The most obvious candidates are those adopting or considering newer technologies. Table 2 provides relevant information. Most sophisticated users often already have the resources or the incentive to upgrade their practices. For instance, larger branch plants located in more industrialized areas and producing for export are already likely to adopt new technologies and may need little additional stimulus.

Manufacturers planning or inclined towards new technology investment may be more promising candidates for outreach efforts. These plants tend to be smaller plants located closer to metropolitan areas. Although all types of industries are represented and all manner of plant-level characteristics can be found among plants planning to adopt new technologies, this result suggests that the a strategy of targeting smaller and intermediate sized plants with services focused in clustered yet accessible locations may be an effective way to stimulate higher levels of new technology use.

5.3 Strategies and policies for modernization

Technology adoption is a complex decision influenced by a variety of plant-level, industry, and business factors. Similarly, policies designed to stimulate technology adoption should be equally complex. The factors used in the multivariate regressions reported here do indicate some policy levers which might affect manufacturing technology adoption. The problem is that few levers are easy to pull and the effects of some are still uncertain. One obvious way for a state like West Virginia to improve technology use is to recruit larger production units (VOLUME), especially those with innovative characteristics. However, Glasmeier (1991) argues that such strategies are unlikely to yield satisfying results in the long-term because such firms have a strong tendency to locate in urban and metropolitan areas with strong cultural amenities and good informational infrastructure. More rural states often have neither. Another policy option would be to assist existing small manufacturers to become bigger (i.e., increase EMPLOY) so that they have more of the characteristics such as financial resources to undertake their own modernization projects. Tax and financial assistance focus could be an integral part of such a strategy, and some studies suggest ways in which these tools can be used (Walker and Greenstreet, 1991). However, the effects of such policies on technology use are largely uncertain and may have counterintuitive effects. More sanguine approaches may be found in aggressively promoting state exports (EXPORT) and supporting worker training schemes (TRAIN). These last two strategies may positively affect plant technology adoption behavior as firms better recognize the capabilities needed to succeed in broader markets and upgrade their workers' skills and productivity in effectively using more advanced manufacturing methods.

Another modernization policy that may affect plant technology choices is to promote greater networking and cooperation among small and medium-sized manufacturers. This approach is attracting increasing attention among economic development specialists (Rosenfeld, 1992) even though the conditions necessary for nurturing these relationships are complex (Hansen, 1991; Storper, 1993). The evidence presented here is mixed. On the one hand, close proximity to clusters of other manufacturers (MFG) is associated with higher levels of technology use. On the other hand, participation in inter-company networks (LINKS) and closer customer supplier relationships (CUST) are not uniformly associated with higher technology use, although customer assistance may result in a greater likelihood of adopting specific organizational technologies.

Finally, there is the policy of promoting technology and industrial extension assistance to firms to aid and stimulate them in selecting and adopting new technologies, methods, and business practices. Up to now, there have been few full-blown appraisals of such intervention efforts (Feller, 1992; Shapira, Youtie, and Roessner, 1996). Many programs are in the early or formative stages and evaluation is generally weak, with diverse approaches and practices being used. Therefore, it would be premature to offer a full-scale prognosis. However, the preliminary evidence does indicate technology assistance has the potential to improve manufacturing performance and firm business practices (National Research Council, 1993; Marshall et al., 1993; Oldsman, 1994; US General Accounting Office, 1991, 1995) and increase the likelihood of plants adopting off-the shelf manufacturing technologies (Tödtling, 1991; Capello and Nijkamp, 1993).

The results found for West Virginia suggest that, even though technology assistance (TECHAID) has not been available for long, it is affecting the technology adoption behavior of plants in the state. This effect has not yet been manifested in the overall level of new technology adoption. However, it may be influencing the adoption of particular technologies such as computer-aided design and engineering. More importantly, perhaps, it seems to be affecting plant attitudes toward new technology investment. Plants that had received assistance planned to adopt, on average, two more new technologies in the next 1-3 years than their non-assisted counterparts.

6. Summary and Conclusion

There is a growing consensus among both public and private policymakers that manufacturers must modernize their production technologies in order to remain competitive in regional, national, and international markets. This paper examined plant modernization by focusing on underlying determinants of technology adoption discussed in earlier studies from economics, geography, and regional science and raised in current debates. The findings can be briefly summarized. Holding all else constant, larger plants located in counties with a large manufacturing sector and producing products in long production runs are more likely to adopt more new manufacturing technologies than other types of plants. Yet the most important factors are plant and industry level factors rather than intra-state regional characteristics. Prominent determinants of technology adoption are the export orientation of the plant, its size, its organizational status, and its formal employee training effort. That is to say, plants that produce for local markets, smaller plants, independently owned plants, and plants without formal employee training programs are less likely to adopt new technologies than other types of plants. These same variables influence the decision to adopt specific technologies, but their importance varies from technology to technology. For instance, long production runs show the strongest association with automated handling systems, computer integrated manufacturing, and various organizational technologies, while batch production is more strongly associated with the adoption of numerical control and computerized numerical control machines.

The paper suggests that there is a role for government-sponsored efforts to encourage plant modernization. The services associated with such policies may be delivered by public, non-profit, or private organizations. In assisting firms to use technology, three approaches are receiving increasing attention from economic development specialists and may deserve additional support. One approach is to directly provide technology assistance to small and medium-sized plants. The results for West Virginia suggest that, although existing programs have not yet created measurable changes in overall technology usage in the studied state, they may have affected the adoption of specific technologies and receptivity to new technology investment. Second, given the demonstrated linkage between training and technology adoption, there is a case for additional public support and stimulation of training. This is especially likely to be useful where training can be improved for existing workers, for example through apprenticeship and skill upgrading. Finally, fostering the clustering of manufacturers and inter-firm cooperation among them may be useful. According to the results reported here, close proximity to other manufacturers and, to some extent, customer assistance are associated with higher levels of technology adoption.

ENDNOTES

1. 1990 gross state product data, as reported in Bergland and Coburn (1995, Table A2). The US Department of Commerce (1992) counts 1,720 manufacturing establishments in West Virginia; private data sources indicate over 2,200 establishments (Harris Publishing Company, 1992).

2. In the terms of the U.S. Standard Industrial Classification (SIC), the industrial categories targeted by the survey were SIC codes 22-26, 28, 30, 32, 33-39, and selected miscellaneous repair services from SICs 73 and 76.

3. For comparison with an earlier study of technology use in West Virginia, see Shapira and Geiger, (1990).

4. A principal components factor analysis with VARIMAX rotation selected six parsimonious dimensions of new technology use representing 60% of data variation. However, when indices created by aggregating factor scores were used as the dependent variable in regression analyses, they did not appreciably alter the results. Because of this finding and in order to retain intuitive interpretation of the results, the aggregated index is used in this section. It is possible that for a plant with multiple lines, a technology may be present but not used in all lines of production. Similarly, while for some technologies (quality control, training, or inter-company networking), a binary (present/not present) measure of adoption is appropriate, for other technologies (e.g. computers, CAD, or robots) it would have been useful to explore the intensity of use (i.e., by a measure like technologies per employee). However, information on the absolute number of particular technologies used was not collected in the survey.

Table 1. Technology Adoption Model: Variable Names, Expected Signs and Definitions

Table 2. Regression Results for Technology Adoption Model

Table 3. Statistically Significant Coefficient Signs for Probit Regressions of Individual Technology Adoption

REFERENCES

Advanced Research Projects Agency, 1993 Technology Reinvestment Project. Program information package (Advanced Research Projects Agency, U.S. Department of Defense, Arlington, VA)

Alderman N, Davies S, 1990, "Modelling regional patterns of innovation diffusion in the UK metalworking industries" Regional Studies **24** 513-528

Alderman N, Fischer M M, 1992, "Innovation and technological change: An Austrian-British comparison" Environment and Planning A **24** 273-288

Antonelli C, 1990, "Induced adoption and externalities in the regional diffusion of information technology" Regional Studies **24** 31-40

Appold S J, Gant J P, 1993, "Agglomeration and plant-level technological change" Paper presented at the 40th Annual North American Regional Science Association Meetings, Houston, TX

Benvignati A M, 1982, "Interfirm adoption of capital-goods innovations" Review of Economics and Statistics **64** 330-335

Berglund D, Coburn C, 1995 Partnerships: A compendium of state and federal cooperative technology programs (Batelle Press, Columbus)

Besant J R, 1982, "Influential factors in manufacturing innovation" Research Policy **11** 117-132

Braga H, Willmore L, 1991, "Technological imports and technological effort: An analysis of their determinants in Brazilian firms" Journal of Industrial Economics **39** 4421-4432

Britton J N H, 1991, "Reconsidering innovation policy for small and medium sized enterprises: The Canadian case" Environment and Planning C **9** 189-206

Brown L A, 1981 Innovation diffusion: A new perspective (Methuen, London)

Brugger E A, Stuckey B, 1987, "Regional economic structure and innovative behavior in Switzerland" Regional Studies **21** 241-254

Capello R, Nijkamp P, 1993, "Industrial and regional variations in consumption network externalities" Paper presented at the North American Regional Science Association Meetings, Houston, TX, November 12-14

Carter C, Williams B, 1957 Industry and technical progress (Oxford University Press, New York)

Cass J, Birnbaum M, 1991 Comparative guide to American colleges (Harper-Collins, New York)

Clifton D S, Edens L R, Johnson H T, Springfield R W, 1989, "Elements of an effective technology assistance policy to stimulate economic development" Economic Development Quarterly **3** 52-57

Davelaar E J, Nijkamp P, 1989, "Spatial dispersion of technological innovation: A case study for the Netherlands by means of partial least squares" Journal of Regional Science **29** 325-346

Davies S, 1979 The diffusion of process innovations (Cambridge University Press, Cambridge)

Dieperink H, Nijkamp P, 1988, "Innovative behavior, agglomeration economies and R & D infrastructure" Empirical Economics **13** 35-57

Dosi G, Freeman C, Nelson R, Silverberg G, Soete L, 1988 Technical change and economic theory (Pinter Publishers, London)

Eisinger P, 1988 The rise of the entrepreneurial state: State and local economic development policy in the United States (University of Wisconsin Press, Madison WI)

Feller I, 1992, "American state governments as models for national science policy" *Journal of Policy Analysis and Management* **11** 288-309

Fogerty M S, Lee J C, 1991 A manufacturing industry cluster approach to technology deployment (Center for Regional Economic Issues, Case Western Reserve University, Cleveland OH)

Friedman D, 1988 The misunderstood miracle: Industrial development and political change in Japan (Cornell University Press, Ithaca, NY)

Gilder G, 1989 Microcosm: the quantum revolution in economics and technology (Simon and Schuster, New York)

Gillies J A, Kruzich R, 1988 The transfer of advanced manufacturing technologies to eastern Kentucky industries (Mountain Association for Community Economic Development, Inc, Berea KY)

Glasmeier A, 1991 The high tech potential: Economic development in rural America (Center for Urban Policy Research, New Brunswick NJ)

Globerman S, 1975, "Technological diffusion in the Canadian tool and die industry" Review of Economics and Statistics **57** 428-434

Hansen N, 1991, "Factories in Danish fields How high-wage, flexible production has succeeded in peripheral Jutland" International Regional Science Review **14,2** 109-132

Harris Publishing Company, 1993 West Virginia manufacturing directory (Twinsburg, OH)

Hicks D A, 1986, "Industrial renewal through technology upgrading in the US metalworking industry" in Technology, regions, and policy ed. J Rees (Rowman and Littlefield, Totowa, NJ)

Industrial Technology Institute, 1987 Fostbelt automation: The ITI status report on Great Lakes Manufacturing (Ann Arbor, MI)

Jaikumar, R, 1986, "Postindustrial manufacturing" Harvard Business Review November-December 69-76.

Jang S, Norsworthy J R, 1992 Technology adoption in US manufacturing: A comparison of foreign-associated and domestic plants Working Paper 92-1, Center for Science and Technology Policy, Rensselaer Polytechnic Institute, Troy NY

Kelley M R, Brooks H, 1988 The state of computerized automation in US manufacturing Harvard University, Kennedy School of Government, Cambridge, MA

Kelley M R, Brooks H, 1991 "External learning opportunities and the diffusion of process innovations to small firms" Technological Forecasting and Social Change **39** 103-125

Kraft K, 1989, "Market structure, firm characteristics, and innovative activity" Journal of Industrial Economics **37** 329-336

LeBrasseur R, Nasierowski W, 1991, "Training and the application of computer-based technology: The case of Ontario manufacturing" Technological Forecasting and Social Change **40** 371-388

MacPherson A, 1988, "Industrial innovation in the small business sector: Empirical evidence from metropolitan Toronto" Environment and Planning A **20** 953-971

MacPherson A D, 1992, "Innovation, external technical linkages and small firm commercial performance: An empirical analysis from western New York " Entrepreneurship and Regional Development **4** 165-183

Mansfield E, 1963, "The speed of response of firms to new techniques" Quarterly Journal of Economics **77** 290-311

Mansfield E, Rapaport J, Romeo A, Villani E, Wagner S, Husic F, 1977 The production and application of new industrial technology (W W Norton and Co, New York)

Marshall J N, Alderman N, Wong C, Thwaites A, 1993, "The impact of government-assisted management training and development on small and medium-sized enterprises in Britain" Environment and Planning C **11** 331-348

National Institute of Standards and Technology, 1995 Manufacturing Extension Partnership: Making a difference for America's manufacturers (US Department of Commerce, Gaithersburg, MD).

National Research Council, 1993 Learning to change: Opportunities to improve the performance of smaller manufacturers (National Academy Press, Washington DC)

North Carolina Alliance for Competitive Technologies, 1985 Making manufacturing and technology work for North Carolina (Research Triangle Park, NC)

Oakey R P, O' Farrell P N, 1992, "The regional extent of computer numerically controlled (CNC) machine tool adoption and post adoption success in small British mechanical engineering firms" Regional Studies **26** 163-175

Oldsman E, 1994 An evaluation of the Industrial Technology Extension Service Report to the New York State Science and Technology Foundation (Nexus Associates, Cambridge MA)

Osborne D, Gaebler T, 1992 Reinventing government: How the entrepreneurial spirit is transforming the public sector (Addison-Wesley, Reading, MA)

Ostrowiecki B, Loomis W, Speers M, Tornatzky L, 1992 Technology needs in four sectors: A field study of MMTC client companies Report to the Midwest Manufacturing Technology Center, Ann Arbor MI

Piore M J, Sabel C F, 1984 The second industrial divide: Possibilities for prosperity (Basic Books, New York)

Rees J, Briggs R, Oakey R, 1984, "The adoption of new technology in the American machinery industry" Regional Studies **18** 489-504

Rephann T, Shapira P, 1994 Survey of technology use in West Virginia manufacturing Regional Research Institute, Research Paper 9401 West Virginia University, Morgantown WV

Rogers, E M 1962, Diffusion of innovations (Free Press, New York)

Romeo A A, 1975, "Interindustry and interfirm differences in the rate of diffusion of an innovation" Review of Economics and Statistics **57** 311-319

Rosenfeld S, 1992 Competitive manufacturing: New strategies for regional development (Center for Urban Policy Research, New Brunswick, NJ)

Sengenberger W, Loveman G, Piore M (ed) 1990, The re-emergence of small enterprises: Industrial restructuring in industrialised countries (International Institute for Labor Studies, Geneva)

Shapira P, 1990, "Modern times Learning from state initiatives in industrial extension and technology transfer" Economic Development Quarterly **4** 186-202

Shapira P, Geiger M, 1990 Modernization in the mountains? The diffusion of industrial technology in West Virginia manufacturing Regional Research Institute Working Paper 9007, West Virginia University, Morgantown, WV

Shapira P, Roessner J D, Barke R, 1995, "Public infrastructures for industrial modernization in the United States" Entrepreneurship and Regional Development **7**, 63-84.

Shapira P, Youtie J, Roessner J D, 1996, "Current practices in the evaluation of U.S. industrial modernization programs" Research Policy (forthcoming)

Simons G R, 1993, "Industrial extension and innovation", in Empowering technology: Implementing a US strategy ed. L M Branscomb (MIT Press, Cambridge MA)

Stoneman P, 1983 The economic analysis of technological change (Oxford University Press, Oxford)

Storper M, 1993, "Regional 'worlds' of production: Learning and innovation in the technology districts of France, Italy, and the USA" Regional Studies **27** 433-455

Sweeney G P, 1987 Innovation, entrepreneurs and regional development (St. Martin's Press, New York)

Tödtling F, 1991, "Spatial differentiation of innovation—locational and structural factors Results of an Austrian study", in Regions reconsidered eds E Bergman, G Maier, F Tödtling (Mansell Publishing, London)

Tödtling F, 1992, "Technological change at the regional level: The role of location, firm structure, and strategy" Environment and Planning A **24** 1565-1584

Tornatzky L G, Fleisher M, Chakrabarti A K, 1990 The processes of technological innovation (Lexington Books, Lexington, MA)

Utterback, J 1974 "Innovation in industry and the diffusion of technology," Science **183** 620-626

US Department of Agriculture, Economic Research Service, 1987 Rural-urban continuum code (Washington DC)

US Department of Commerce, Bureau of the Census, 1989 Current industrial reports, manufacturing technology 1988 (USGPO, Washington DC)

US Department of Commerce, Bureau of the Census, 1993 County and city data book (USGPO, Washington)

US Department of Commerce, Bureau of the Census, 1992 County business patterns (USGPO, Washington)

US Department of Commerce, Bureau of Economic Analysis, 1993 Regional economic information system Washington DC

US Department of Transportation, Federal Highway Administration, 1987 Highway performance monitoring system Washington, DC

US General Accounting Office 1991, US efforts to enhance the competitiveness of small manufacturers (GAO/RCED-92-30, Washington DC)

US General Accounting Office 1995, Manufacturing extension programs: Manufacturers' views of services (GAO/GGD-95-216BR, Washington DC)

Variyam J, Kraybill D S, 1993, "Small firms' choice of business strategies" Southern Economic Journal **60** 136-145

Walker R, Greenstreet D, 1991, "The effect of government incentives and assistance on location and job growth in manufacturing" *Regional Studies* **24** 15-30

Wiarda E, 1989, "Fixing what's broke where it counts: Agglomeration in the core industrial economy" TechnEcon **1,2** 1-13 (Industrial Technology Institute, Ann Arbor, MI)

Wozniak G, 1987, "Human capital, information, and the early adoption of new technology" Journal of Human Resources **22** 101-112

Young R C, Francis J D, Young C H, 1993, "Innovation, high-technology use, and flexibility in small manufacturing firms" Growth and Change **24** 67-86

Youtie J, Shapira P, Roessner, J D, 1995 Manufacturing assistance program needs assessment guide. Volume 1: Regional needs assessment approaches (Aspen Institute, Washington DC)

Table 1. Technology Adoption Model: Variable Names, Expected Signs and Definitions

Dependent Variable	
TECHUSE	Total number of new technologies used by plant, from this set of technologies: Shop-floor personal computers, used for manufacturing; Personal computers for non-manufacturing purposes; Data collection devices; Numerical control machines (NC); Computerized numerical control machines (CNC); Programmable controllers (PLC); Automated in-process inspection or sensors; Automated material handling systems; Computer-aided design (CAD); Computer-aided engineering; Robotics; Lasers; Flexible manufacturing system (FMS); Computer-integrated manufacturing (CIM); Production, planning, and inventory control software; Statistical process control (SPC); Just-in-time delivery systems (JIT); Employee involvement program (EIP); Total quality management (TQM); Computer networks (inter-plant or inter firm).
Independent Variables (expected sign in parenthesis)	
Plant Characteristics	
EMPLOY (+)	Number of plant employees, 1993.
GROW (+/-)	Growth rate of plant employment, 1989-93.
BRANCH (+)	Ownership (1 if plant is branch plant, 0 if it is independent).
UNION (+/-)	Employee Unionization (1 if employees are unionized, 0 if not).
TRAIN (+)	Plant formal training program (0 if plant has no program, 1 if it does).
AGE (+/-)	Age of plant.
MFGPROC (+)	Manufacturing engineering and process improvement (1 if it is performed at plant, 0 if not).
Industry Characteristics	
CUSTOM (-)	Make parts or products one-at-a time to customers' orders (1=Yes, 0=No).
BATCH (+)	Make products in batch runs of a few dozen to a few hundred (1=Yes, 0=No).
VOLUME (-)	Make products in long production runs (1=Yes, 0=No).
SMPROC (-)	Process materials in small volumes (1=Yes, 0=No).
LGPROC (-)	Process materials in large volumes (1=Yes, 0=No).
REMAN (-)	Remanufacture or refurbish machines or parts (1=Yes, 0=No).
DEFENSE (+)	Percentage of sales to Defense Department or defense subcontractors.
EXPORT (+)	Percentage of plant sales outside of West Virginia.
LINKS (+)	Number of intercompany networks participated in.
CUSTAID (+)	Customer assistance (1 if major customers have assisted to improve quality or solve technical problems, 0 if not).
Region	
ADJCODE[1] (-)	Urban-rural code (1 if plant is located in metropolitan county, 2 if plant is located in county adjacent to metropolitan county, 3 if plant is located in county that is not adjacent to metropolitan county).
HWY[2] (+)	Presence of interstate highway (1 if highway in county, 0 if not).
COLLEGE[3] (+)	Number of students enrolled in colleges or universities in county.
EDHIGH[4] (+)	Percent of county adults (25 years and older) completing high school, 1990.
RMFG[5] (+)	Rate of change in county manufacturing employment, 1982-91.
RTOT[5] (+)	Rate of change in total county employment, 1982-91.
MFG[5] (+)	Total county manufacturing employment, 1991.
Policy	
TECHAID (+)	Technology assistance from West Virginia University Industrial Extension Service (1 if plant has received assistance and 0 if it has not.

Data Sources

Plant, industry, and policy variables: 1993 Survey of Technology Use in West Virginia Manufacturing (Rephann and Shapira, 1994).

Regional variables:

[1] US Department of Agriculture, Economic Research Service (1987)
[2] US. Department of Transportation, Federal Highway Administration (1987)
[3] Cass and Birnbaum (1991)
[4] US. Department of Commerce, Bureau of the Census (1993)
[5] U.S. Department of Commerce, Bureau of Economic Analysis (1993)

Table 2. Regression Results for Technology Adoption Model

	Technologies Currently in Use	Technologies Planned[a]
Variable	Coefficient	Coefficient
Plant Characteristics		
EMPLOY	0.0084***	-0.0004
GROW	-0.0016	0.0041***
BRANCH	0.9379*	0.0115
UNION	0.4543	1.0853***
TRAIN	1.4173**	0.1819
AGE	-0.0143	-0.0082
LINKS	0.1493	0.0068
MFGPROC	0.3586	0.1439
CUSTAID	0.2979	0.1016
Industry Characteristics		
CUSTOM	-0.7723	0.0549
BATCH	0.7295	0.3010
VOLUME	1.3596**	-0.3151
SMPROC	-0.2595	0.0563
LGPROC	0.9350	0.3353
REMAN	1.2637**	0.6987*
DEFENSE	0.0366	0.0361**
EXPORT	0.0205*	0.0074
Region		
ADJCODE	0.3998	-0.4775**
HWY	-0.3936	-0.3512
COLLEGE	0.0000	0.0001
EDHIGH	-0.0032	-0.0182
RMFG	-0.0164	-0.0025
RTOT	-0.0055	0.0100
MFG	0.0003**	0.0000
Policy		
TECHAID	1.4547	2.2786***
Intercept	1.0933	2.1299
R^2	.53	.33
Root MSE	2.96	3.14
Observations	202	202

***α =.01, **α =.05, *α =.10

Table 3. Statistically Significant Coefficient Signs for Probit Regressions of Individual Technology Adoption

Technology	In Use[a]	Positive Sign Coefficient[b]	Negative Sign Coefficient[b]	Log-Likeli-hood	X^2
Personal computers: non-manufacturing	69%	UNION (+) EXPORT (+)		-99.6	29.0
Software for production, planning, or inventory control	55%	LGPROC (+++) EMPLOY (++) UNION (++) HWY (+)		-107.0	43.0
Employee involvement program	47%	EXPORT (+++) EMPLY (++) TRAIN (++) CUSTAID (++) VOLUME (++) MFG (+)	BATCH (--)	-99.2	72.0
Total quality management	35%	TRAIN (+++) VOLUME (++) EMPLOY (+) GROW (+) MFG (+)	HWY (--) RMFG (--)	-90.2	80.5
Computer-aided design	33%	MFGPROC (+++) UNION (++) TECHAID (+)		-92.1	76.6
Programmable controllers	33%	EMPLOY (++) EXPORT (++)	CUSTOM (--) HWY (--)	-83.3	92.5
Statistical process control	30%	CUSTAID (+++) UNION (++) LGPROC (+) EXPORT (+) EDHIGH (+)		-67.5	107.5
Just-in-time delivery	28%	BATCH (++) VOLUME (++) TRAIN (++) CUSTAID (+) EXPORT (+)	AGE (-)	-88.9	57.9
Computer-aided engineering	26%	EMPLOY (++) TECHAID (++) UNION (+)	GROW (-)	-86.9	70.1

Technology	In Use[a]	Positive Sign Coefficient[b]	Negative Sign Coefficient[b]	Log-Likeli-hood	X^2
Personal computers: manufacturing	23%	TRAIN (++) EMPLOY (+) MFG (+)	CUSTOM (-)	-88.7	54.7
In-process sensors	20%	MFG (+++) EMPLOY (++) BRANCH (+)	CUSTOM (--) HWY (--)	-51.1	98.5
Automated material handling	20%	VOLUME (++) EDHIGH (+) RMFG (+)		-63.9	67.5
Computer networks: inter-plant or inter-firm	19%	EMPLOY (+) BRANCH (+)	RMFG (-)	-62.6	80.6
Data collection devices	18%	LGPROC (+)	CUSTOM (-)	-57.3	72.0
Computer numerical control	17%	BATCH (+++) REMAN (++)	LINKS (--)	-54.5	71.4
Numerical control	14%	UNION (+++) LGPROC (++) COLLEGE (++) REMAN (+) DEFENSE (+) BATCH (+)		-47.4	69.2
Lasers	11%	SMPROC (++) BRANCH (+) TECHAID (+)	CUSTAID (---)	-33.8	65.6
Computer integrated manufacturing	7%	TECHAID (++) EMPLOY (+) VOLUME (+)		-17.9	59.7
Flexible manufacturing systems	4%	EMPLOY (+)		10.2	52.6
Robotics	3%	--	--	--	--

[a]Percent of establishments using technology, based on weighted survey responses from 299 West Virginia manufacturers.
[b]Based on 202 responses included in probit regressions. Statistical significance (in parenthesis): +++or--- α =.01; ++or-- α =.05; +or- α =.10