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# Rural Manufacturing on the Crest of the Wave

## A Study of Rural-Urban Technology Use

H. Frederick Gale, Jr.

**Rural Manufacturing on the Crest of the Wave: A Study of Rural-Urban Technology Use**
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## Abstract

The study compares rural and urban technology use in a 1993 sample of manufacturing plants from five industries. Comparisons by plant size, industry, and region show similar rates of technology use by metro and nonmetro plants. Multivariate analysis of technology use shows that nonmetro location has no effect when plant and location characteristics are held constant. Local characteristics, including schooling and minority population, affect technology use in metro counties, but not in nonmetro counties. The study concludes that technology diffusion is not a major obstacle to rural economic development.

**Keywords:** technology adoption, rural manufacturing, labor force, education, Poisson regression

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## Introduction

Advanced technology use is often recognized as a key factor in determining competitiveness of manufacturing businesses and overall economic performance of national and regional economies (Baranson; Baldwin, Diverty and Sabourin; OECD). Technological advance within a region's firms can improve a region's economic prospects by giving those firms a competitive advantage in local, national, and international markets, while regions that lag in technology use may see their economic base eroded (Thwaites and Oakey). Technology is believed to be particularly important for U.S. businesses, since higher productivity and innovation resulting from technology use can offset the relatively high labor costs of U.S. plants compared with competitors in the Pacific Rim countries, other parts of Asia, and Latin America.

Some observers are concerned that rural areas may fall behind urban areas in the technology race. Models of technology diffusion and product-industry cycle often assume that new inventions and techniques are devised and adopted first in cities, where contacts and communication are plentiful, later spreading to rural areas (Hudson; Moomaw). Lagging rural technology use could result from spatial barriers to information flows, the relatively small number of contacts with information sources by rural businesses, the mix of rural industries, their size, structure, and organization, availability of financial capital, and characteristics and attitudes of rural managers and workers. Diffusion of technology from rich to poor countries has been a focus of much discussion in the literature, but few studies have investigated the diffusion of technology from urban to rural areas within the same country. The diffusion of technology across regions has important implications in today's increasingly knowledge-based economy. Influential work by Romer argues that ideas and innovations are keys to economic growth. This theory suggests that rural areas will lag behind urban regions if they lack access to knowledge about technology and other innovations.

Several previous studies suggest that rural areas lag in technology use. Harrison, Kelley, and Gant found that use of programmable automation in metalworking plants is highest in suburban locations and lower in central city and rural locations. Little and Triest find similar results using a broader set of technologies. Kusmin finds a lower rate of computer use by workers in nonmetro areas.

The purpose of this study is to determine if technology use in rural manufacturing plants lags behind that in urban plants, and to explore the plant and location characteristics associated with technology use. I evaluated the use of 17 advanced technologies in a sample of urban and rural manufacturing establishments in five industries. I made rural-urban comparisons by plant size, multiunit firms, industry, region, and by level of schooling and minority population in the plant's local area. A multivariate analysis estimated the effects of urbanization, local area characteristics, and plant characteristics.

## Technology Adoption and Diffusion

Information about new technology may reach urban firms before it reaches rural firms. The faster flow of information in densely populated urban areas is often cited as the economic advantage of cities (Glaeser et al.; Harrison, Kelley, and Gant). If information is the chief barrier to adoption, then a higher rate of technology use may be observed among urban firms compared with rural firms at a point in time. However, technologies are not necessarily appropriate for all firms. Nasbeth and Ray identify six factors that influence the adoption of technologies:

1. Technical applicability--the technology may or may not be applicable to the whole range of production processes.
2. Profitability--the economic advantage relative to older processes or technologies.
3. Finance--the availability and cost of capital needed to implement the technology.
4. Size, structure, and organization of firms.
5. Other factors--research and development, information, labor market situation, demand conditions.
6. Management attitudes.

Geographic differences in rural and urban technology use may arise from barriers to the flow of knowledge or from rural-urban differences in the above factors. For example, a higher concentration of "low-tech" industries in rural areas may result in lower technology use because technologies are not technically applicable for rural industries. Differences in access to financial resources, plant size, or management attitudes and worker characteristics could also result in differing technology use. Clearly, it is important to consider characteristics of the plant in analyzing technology use. This is particularly important in the present study where I look at technology use in a cross section of plants from diverse industries. In addition, some technologies, such as communications technologies, may have greater benefits for rural firms. The mix of plants and manufacturing functions in rural and urban areas may also affect technology use. Knowledge-intensive design and engineering functions are often concentrated in urban areas, while the more routine fabrication and assembly processes make up a larger share of rural activity. With this in mind, I also report some results for three sub-groups of technologies.

## Data

The Census Bureau's 1993 Survey of Manufacturing Technology (SMT) is a sample survey of 8,336 establishments with 20 or more employees from 5 major manufacturing groups (SIC codes 34-38): Fabricated Metal Products (SIC 34), Industrial Machinery and Equipment (SIC 35), Electronic and Other Electric Equipment (SIC 36), Transportation Equipment (SIC 37), and Instruments and Related Products (SIC 38).[1] These industries are predominantly urban, but are nevertheless an important component of the rural manufacturing base. In 1992, they accounted

[1] The 1993 SMT follows a similar survey conducted in 1988. A 1991 SMT asked questions related to reasons for adoption. The samples for all 3 years were drawn independently of one another.

for 30 percent of nonmetro and 45 percent of metro manufacturing employment. These industries also tend to be among the more technologically advanced manufacturing industries.

The SMT is a stratified random sample of establishments chosen from the file used by the Census Bureau to enumerate establishments for the census of manufacturing. The sample was restricted to establishments with 20 or more employees, and larger establishments were sampled at a higher rate than small establishments. Thus the sample contained a relatively higher proportion of large establishments than the total population. The sampling process did not have a geographic stratum; it is assumed that metro and nonmetro establishments had equal chances of being selected for the sample. Tabulations of the data were produced using the Census Bureau's sample weights. The sample included 8,016 observations with usable information, including 1,446 plants located in nonmetro counties and 6,570 located in metro counties.

The SMT questionnaire asked respondents to report their use of 17 advanced technologies, organized into 5 general areas:

1. Design and engineering
    a. Computer-aided design/engineering (CAD/CAE).
    b. Use of CAD output to control manufacturing machines (CAD/CAM).
    c. Digital representation of CAD output used in procurement activities.
2. Fabrication/machining and assembly
    a. Flexible manufacturing cells (FMC) or systems (FMS).
    b. Numerically controlled (NC)/computer numerically controlled machines (CNC).
    c. Materials-working lasers.
    d. Pick and place robots.
    e. Other robots.
3. Automated materials-handling
    a. Automatic storage and retrieval system (AS/RS).
    b. Automatic guided vehicle systems (AGVS).
4. Automated sensor-based inspection and/or testing
    a. Performed on incoming or in-process materials.
    b. Performed on final product.
5. Communication and control
    a. Local area network (LAN) for technical data.
    b. Local area network (LAN) for factory use.
    c. Intercompany computer network linking plant to subcontractors, suppliers, and/or customers.
    d. Programmable controllers.
    e. Computer(s) used for control on the factory floor.

Respondents reported whether each technology was currently in use at the plant, the time frame when the plant began using the technology, and the most important reason for using each technology. Most of the SMT technologies are used in production processes, but some of the technologies used for design (CAD/CAE), inspection (use of sensor-based inspection/testing equipment), and communications activities (intercompany network) may not be directly related to production processes. Many of the technologies, such as robots and automated materials-handling systems are labor-saving devices that promote the efficient movement of materials through the production process. Other technologies are used to ensure precision in production process and product quality. The use of computers to control aspects of the design and production processes increases the degree of flexibility in the manufacturing operation and permits rapid response to changes in product specifications or orders for new products. Computerized design and manufacturing processes make short production runs more cost-effective, permitting more customized production to meet individual customers' needs. Communications technologies improve flexibility and efficiency through the exchange of information between different points in the production process within a manufacturing plant, and by enabling swift communication with suppliers, subcontractors, and customers. Additional information about these technologies is available in Little and Triest and Baldwin, Diverty, and Sabourin.

The survey also asked plants to report on 14 plant characteristics, including the plant's age, nature of manufacturing process, and information about the plant's market, research and development activity, and training. The survey results do not give a complete picture of differences in urban and rural technology use since the survey excluded many of the industries common in manufacturing areas and also excluded the smallest manufacturing plants. However, the survey data are nevertheless helpful in identifying possible nonmetro-metro differences in technology adoption within these five industries. The effects of location characteristics on technology use are investigated by merging the data with secondary data describing the manufacturing plant's county or commuting zone. Labor force characteristics, presence of institutions of higher education, racial makeup of the population, and local industrial specialization variables are constructed from county-level Census of Population and County Business Patterns data.

"Metropolitan" and "nonmetropolitan" are generally equated with urban and rural. This study makes many comparisons based on this distinction. I employed a modified version of the Economic Research Service's rural-urban continuum (often known as Beale codes) to distinguish between cities of different sizes and nonmetro areas of varying degrees of "ruralness." I collapsed the 10 Beale codes into 7 categories in descending degree of urbanization: large, medium, small and fringe metro areas, urbanized nonmetro areas, less-urbanized/rural nonmetro adjacent to metro area, and less-urbanized/rural nonmetro not adjacent to a metro area.

## Rates of Technology Use by Metro and Nonmetro Plants

Figure 1 shows the metro and nonmetro distribution of plants by number of technologies used. Patterns of use between metro and nonmetro plants are similar. The bulk of both metro and nonmetro respondents reported low technology use. Nearly one in four establishments reported using none of the 17 technologies. Thirteen percent of metro and 15 percent of nonmetro plants used one technology. Only 3 percent used 9 technologies, and just under 5 percent used 10 or more technologies. Relatively few nonmetro plants reported using two technologies (8 percent) and a relatively large percent of metro plants reported using 3 technologies (13 percent). This may possibly represent the adoption of certain technologies as a group, or it may just be an artifact of the data.

### Metro-Nonmetro Comparison

Table 1 indicates that use of individual technologies by nonmetro plants is on a par with that of metro plants. The usage rate by metro plants exceeds that of nonmetro plants for only 5 of the 17 technologies in table 1. Nonmetro usage rates exceed metro rates for eight technologies, and the metro-nonmetro rates are not significantly different for the remaining four. Metro plants have the greatest advantage in the use of CAD/CAM and LAN for technical data, but, even for these technologies, the difference in usage is 3 percentage points or less. On the other hand, nonmetro usage rates exceed metro rates by 4 percentage points or more for five technologies. The greatest nonmetro advantage is in use of intercompany networks. Nonmetro plants apparently favor this technology to overcome the disadvantage of remote locations. Nonmetro plants lead metro plants by 4 percentage points or more in flexible manufacturing cells, both types of robots, and computers for control on the factory floor. The most commonly used technology is CAD/CAE, used by nearly 60 percent of establishments, but only about one in four plants used CAD/CAM to control manufacturing machines, and 9.5 percent of nonmetro plants used CAD output in procurement activities.

Nearly half of plants used numerically controlled machines. Communications and control technologies were popular among nonmetro plants; each of the technologies in this category was used by more than 20 percent of nonmetro plants. The least frequently used technologies were automated materials-handling technologies and materials-working lasers. Materials-working lasers were used by 4.4 percent of nonmetro plants, automatic storage and retrieval systems were used by 2.1 percent, and automatic guided vehicle systems were used by 1.4 percent of nonmetro plants.

While the comparison of metro and nonmetro technology use in table 1 seems to reject the existence of a rural technology gap, this simple comparison between metro and nonmetro plants may mask differences among metro areas of different sizes and nonmetro areas of varying degrees of urbanization. Urbanization may have different effects on different types of technologies as well. Figures 2 through 4 show a more detailed look at use of the three most commonly used categories of technology by modified Beale code. Figure 2 shows the mean number of design and engineering technologies, figure 3 shows fabrication and machining technologies, and figure 4 shows communications and control technology use.

The picture emerging from figures 2, 3, and 4 suggests a more complex geographic pattern of technology use than portrayed by the simple metro-nonmetro comparison. Use of design and engineering technology tends to be highest in metro fringe and lowest in the most rural counties. There is little difference between other metro county types. Among nonmetro county types, use of design and engineering technologies falls slightly as counties become more remote--from an average of 0.96 for urbanized nonmetro counties to 0.87 for less urbanized non-adjacent. The use of fabrication and machining technologies shows a similar pattern of decline among nonmetro county types, but among metro county types fabrication and machining technology use is lowest in the largest urban areas. Harrison, Kelley and Gant found a similar pattern in their study of programmable automation in metalworking establishments. This may reflect the shift of fabrication and assembly activity away from large cities in the "rust belt" and other traditional manufacturing regions to smaller cities where labor and land costs are lower. The higher use of design and engineering technologies in urban and suburban areas reflects the continued concentration of those functions in urban centers. Urbanization seems to be least important in use of communications and control technologies (fig. 4). Use of these technologies is highest in small and fringe metro areas, followed closely by the two most rural categories. Core metro areas show the lowest use of communications and control technologies. This appears to reflect the greater need for communications in more remotely located plants.

While some interesting patterns emerge from figures 2, 3, and 4, the differences among county types are modest. Within each urbanization category there is considerable variation among plants of different types. In the analysis below I examine the association between technology use and selected plant characteristics. I also look at the effect of various location characteristics besides urbanization that may be associated with technology use.

**By Plant Size**

Figure 5 shows a strong positive association between plant size and the number of technologies used, and little difference appears between metro and nonmetro plants of similar sizes. The smallest plants in the sample, those with 20 to 99 employees, used an average of 2.4 out of the 17 SMT technologies. Medium-sized plants with 100 to 499 employees used about 4.8 technologies, and the largest plants used about 8 technologies per plant. The metro plants had slightly higher averages for the large and small plants, while nonmetro plants were slightly higher for medium size plants. In each case, the difference in means was 0.3 or less. Clearly the plant size effect overshadows any urbanization effect. The positive association between technology use and plant size is not surprising. Larger plants may have a wider range of activities and thus may employ a wider range of technologies. Also, larger plants may be more innovative or may have access to a larger pool of capital to invest in new equipment and machinery. On the other hand, causation may run in the opposite direction: innovative technology-intensive plants may be more successful and grow faster than other plants, resulting in the observed association between size and technology use.

**Multiunit firms**

Multiunit firms use nearly twice as many technologies as single-unit plants (fig. 6). Again, the multiunit effect outweighs any metro-nonmetro effect. Single units use an average of 2.7 technologies, compared with 4.8 for multiunits. This again suggests that plants belonging to larger firms have better access to information and capital to implement new technologies.

## By Industry

Table 2 shows the average number of technologies used by metro and nonmetro plants in each three-digit SIC industry covered by the SMT. Industries are ranked based on nonmetro technology use. The top users of technology are Electrical Industrial Apparatus, Engines and Turbines, Guided Missiles, and Measuring and Controlling Devices. The average number of technologies used by nonmetro plants in these industries was between 5 and 5.7. At the bottom of the list are Ophthalmic Goods, Ship and Boat Building, Miscellaneous Transportation Equipment, and Metal Services nec. Nonmetro plants in these industries averaged between 0.5 and 1.7 technologies. Thus, there is a fairly wide range in technology use across industries. Fourteen industries averaged 4 to 4.9 technologies, 11 averaged 3 to 3.9, and 6 averaged 2.0 to 2.9. In nonmetro-metro comparisons, nonmetro plants used more technologies than metro plants in 21 industries, and metro plants came out ahead in 18 industries. Nonmetro-metro differences are larger than in other comparisons. The nonmetro advantage exceeded 1 technology in 11 industries, but metro plants had an advantage greater than 1 only in the Ophthalmic Goods industry.

## By Region

Different regions of the country vary in their degree of urbanization, population density, industrial structure, and rural-urban linkages. These factors could lead to regional variations in technology use. Figure 7 shows mean number of technologies for metro and nonmetro portions of the nine Census regions. The most noticeable feature is greater variation among nonmetro regions than among metro regions. Nonmetro plants averaged the highest number of technologies in the New England (4.3 technologies), Mid-Atlantic (3.8), and East North Central (4.1) regions. Nonmetro plants had a lower average in the southern and western regions, with the lowest average in West South Central (2.0) and Mountain (2.3) regions. Metro regions showed less geographic variation, ranging from 3.8 in the Mountain region to 2.88 in the West South Central and Pacific regions. Nonmetro manufacturers in New England, Mid-Atlantic, East North Central, and Pacific regions compared favorably with their metro neighbors in technology use. Nonmetro plants tended to be behind their metro counterparts in the West South Central and Mountain regions. This pattern suggests that rural manufacturing in the Northeast, Midwest and Southeast may be relatively well integrated into the mainstream of the economy, while manufacturers in the relatively remote rural areas of the Southwest and Mountain regions may be more disconnected, resulting in a slight lag in technology use. Regional differences in technology use also reflect differences in the mix of industries from region to region.

## By Schooling Quartile

The education level of workers in a region may be expected to affect technology use. Better educated workers may be better-equipped to learn new tasks and operate advanced machinery. Managers in areas with higher education levels may also be better informed and more willing to try new ideas. The effect on technology use could be through a slower rate of diffusion due to lower education, i.e. otherwise-equal plants may be slower to adopt in areas with a less-educated workforce. The effect could also be indirect as high-technology early-adopter plants shun locations in areas with low education and concentrate in more-educated areas.

No information is available on the characteristics of the SMT plants' work force. To measure the effects of education, I used average years of schooling for persons age 25-44 in the plant's local area, estimated from the 1990 Census of Population. The 25-44 age group is the working-age cohort that has recently completed its schooling. This measure was intended to capture the characteristics of the local labor force that the plant draws from. This is admittedly a crude measure, and ignores the quality of education and the mix of college and technical school graduates. Other measures, including the percent of college graduates and percent of high-school dropouts were available, but these other measures are highly correlated with years of schooling, so there is little to be gained by considering these other measures separately.[2] Counties were aggregated into commuting zones (Tolbert and Sizer), and an average years of schooling measure was computed for each commuting zone (CZ). Commuting zones represent the broader labor market that the plant draws its labor force from. The CZ's were ranked based on the schooling measure and divided into quartiles. Average technology use was computed for metro and nonmetro plants in each quartile. More than half of the sample were in metro counties in the top schooling quartile. Nonmetro plants were evenly divided across schooling quartiles. Schooling averages were 13.3 for the top quartile, 12.9 upper middle, 12.6 lower middle, and 12.1 for the lowest quartile.

Figure 8 shows the average number of technologies per plant by schooling quartile for metro and nonmetro plants. There is a weak association between technology use and schooling. Nonmetro plants in the highest quartile have the highest average technology use, and nonmetro plants in the lowest quartile have lower technology use than other nonmetro plants, but technology use in the nonmetro lower-middle quartile is higher than in the upper-middle quartile. Among metro plants, those in the top two quartiles have higher technology use than those in the lower two quartiles, but technology use in the lowest metro quartile is higher than in the lower-middle quartile. Technology use in the highest metro quartile is only slightly higher than the upper middle quartile.

## By Percent Minority Population

Areas with predominantly minority populations may be underserved by formal and informal networks and institutions that transmit information about new technologies due to cultural barriers or discrimination. I ranked counties based on the percent nonwhite population reported in the 1990 Census of Population and again formed quartiles based on minority population percentage. I used the county rather than the commuting zone, because minority population is

[2]Measures of per capita and per-pupil local education expenditures were also used in preliminary analysis, but these did not seem to be satisfactory measures of education quality. Economies of scale are important in education expenditures, hence larger urban areas have lower per capita and per-pupil expenditures, regardless of quality.

often concentrated in certain counties within a CZ. Most of the metro plants were in the two quartiles with the highest concentration of minorities. Only 159 metro plants were in the quartile with the smallest minority percentages. Minority population does not seem to be a deterrent to manufacturing plant location. Plants were distributed more evenly across nonmetro minority quartiles.

Figure 9 shows lower technology use in counties with the most concentrated minority population for both metro and nonmetro plants. Among metro counties there seems to be a relationship between technology and minority population, as technology use is highest in the counties with the fewest minorities. Among metro plants, technology use rises from 3.7 in the highest minority quartile to 4.9 in the lowest quartile. This pattern is not observed among nonmetro counties, however. Although the most heavily minority nonmetro counties have clearly lower technology use (3.8), the upper-middle quartile has slightly higher technology use (4.7) than the lower-middle and lowest quartiles (both with 4.6).

## A Multivariate Analysis of Technology Use

Clearly, a number of different factors affect the use of technology, including various characteristics of the plant and its location. Comparisons based on a single characteristic, such as metro-nonmetro location, plant size, or local schooling, leave questions unanswered. As we compare metro and nonmetro plants, for example, we do not hold other characteristics constant. A multivariate analysis can address this problem by estimating the effect of multiple characteristics simultaneously. The results show the partial effect of each characteristic, holding other characteristics constant. In this section, I estimate regression equations using the number of technologies per plant as the dependent variable.

In this analysis, I used the following plant characteristics as explanatory variables: (1) a set of three-digit industry SIC code dummy variables, (2) three plant age dummies, corresponding to plants 5-15 years old, 16-30 years old, and more than 30 years old (the coefficients show technology use relative to the excluded category: plants less than 5 years old); (3) the logarithm of plant employment (a measure of plant size); (4) a dummy variable equal to 1 if the plant is part of a multiunit firm, 0 if a single-unit plant, (5) six categorical dummies representing price of output, (6) a dummy variable equal to 1 if the plant's manufacturing process is fabrication and 0 if it involves only assembly or other activities, and (7) a dummy variable equal to 1 if a plant produces products to military specifications.

Two measures of local agglomeration effects are included (Carlino; Moomaw; Mulligan). Dummy variables based on the modified Beale codes used earlier in this report represent urbanization. I have also collapsed the metro categories into "core metro" and "other metro" to reduce the number of categories to five. A location quotient for the plant's two-digit industry in its commuting zone is an indicator of localization effects--the local concentration of the plant's industry--and was also used by Carlino and Goss and Vozikis. A concentration of plants in a particular industry is expected to speed adoption of technologies at that location, thus a positive coefficient is expected. A greater concentration of a particular industry in a location is expected to generate better information networks and higher technology use. The location quotient is the ratio of the commuting zone's share of employment in the two-digit industry to the U.S. share for that industry (obtained from 1992 County Business Patterns). Regional dummy variables corresponding to the nine Census divisions are included to capture regional differences.

Two indicators of local work force quality at the plant's location are also introduced: average years of schooling for persons age 25-44, and the percent of the working-age population (persons age 18-64) who are over age 55. Both are commuting zone-level observations from the 1990 Census of Population. A more educated work force is expected to be associated with greater use of advanced technology, thus a positive sign is expected for this variable. An older work force is expected to have a negative association with technology use.

Percent minority population is included to capture possible effects that impede technology use in areas with nonwhite populations.

The presence of educational institutions may be associated with greater information flow and training opportunities for workers and managers. I included dummy variables for the presence of public 2-year and 4-year colleges in the county. I included only public institutions, because most technology-related work is in public institutions, and private institutions are less likely to serve local industry through outreach programs and worker training. These data are from the annual National Center of Education Statistics Integrated Postsecondary Education Data System survey of educational institutions. The data do not distinguish among different types of 4-year institutions (i.e., research universities vs. teaching-oriented colleges).

**Mean Values**

Table 3 summarizes mean values for explanatory variables used in the analysis, weighted with sample weights. Overall, nonmetro plants had slightly higher average technology use (3.71) than metro plants (3.48). Nonmetro plants led in the use of fabrication and machining and communication and control technologies. Over 60 percent of metro plants (and about half the entire sample) were in the largest metro areas, followed by 26 percent in medium metro areas. About 8 percent of metro plants were in small metro areas and 4 percent in fringe metro counties. Nonmetro plants were split fairly evenly among urbanized nonmetro counties, less-urbanized adjacent to a metro area, and less-urbanized not adjacent to a metro area.

Nonmetro plants in the sample tended to be larger than metro plants (log employment 4.39 vs. 4.13) and more likely to be part of multiplant firms (48 percent vs. 36 percent). This may account for the higher nonmetro technology use, since these two characteristics are strongly related to technology use. Nonmetro plants were less likely to build products to military specifications and more likely to be involved in fabrication. A higher proportion of metro plants were new (13 percent under 5 years old vs. 8 percent nonmetro), and about one-fourth of plants in both metro and nonmetro counties were more than 30 years old.

Nonmetro counties tended to have higher location quotients, schooling (12.69 years for nonmetro plant commuting zones vs. 13.09 for metro), an older labor force (15.16 percent age 55-64 vs. 13.44 percent for metro), and lower concentration of minority population (9.3 vs. 19.1 percent). Only one-third of nonmetro counties had a 2-year college and only 16 percent had a 4-year college. Metro counties were much more likely to have both types of colleges.

**Regression Results**

Since the dependent variable takes on integer values from 0 to 17, Poisson regression methods are more appropriate than ordinary least squares (see appendix). Tests of overdispersion indicated that the restriction that the mean and variance of the Poisson parameter are equal was not valid. Therefore the negative binomial generalization of the Poisson specification is more appropriate. The tables report the marginal effects of each explanatory variable (computed from the regression coefficients evaluated at mean values) and t-values. Intercept values and coefficients for industry and region dummy variables are omitted from the tables to reduce clutter. I estimated a model for total technology use and for use of the three most popular technology groups to test for metro-nonmetro differences, holding plant and location characteristics constant. I then estimated separate metro and nonmetro models to investigate differences in effects of the explanatory variables for metro and nonmetro plants.

Table 4 shows the results of the full model. None of the Beale code dummy variables was significantly different from zero, indicating no urbanization effects. Most of the plant characteristics were significant. Plant size, multiunit firms, fabrication, and military specifications were all positively associated with technology use. Older plants used fewer technologies.[3] Three location characteristics were significant. Schooling was positively associated with technology use, and labor force age and minority population were negatively associated with technology use. The location quotient and presence of educational institutions were not significant. An increase in schooling of 1 year was associated with an increase in number of technologies used by a plant of .25. An increase in percent of older workers of one standard deviation (4.5 percentage points) was associated with a decrease of .22 technologies. An increase in minority population of one standard deviation (30 percentage points) was associated with a decrease in technologies of .33. Effects of plant characteristics were larger in magnitude. Doubling plant employment raised technology use by 1.34. Producing to military specifications was associated with use of .49 more technologies, fabrication was associated with .98 more technologies, and multiplant firms used .60 more technologies, other things equal.

The results indicate that agglomeration measures (Beale code dummies and location quotient) are not important determinants of technology use. Plant characteristics appear to be more important than location characteristics, but it should be kept in mind that location characteristics are measured with much less accuracy than plant characteristics. If we could measure more precisely the location characteristics that influence technology use, the effects of these variables

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[3]The plant age effect is interesting because it contrasts with the finding by Dunne that plant age is not important. Results from alternative specifications indicate that this result is sensitive to the inclusion of the military specifications variable in the model.

might have larger magnitude.

Table 5 shows three models estimated for three technology types: design and engineering. fabrication and machining, and communications and control technologies. The negative binomial model for fabrication and machining technologies failed to converge, so results of a Poisson regression are shown for that technology group. Again, the results indicate almost no effects of urbanization. Only the core metro coefficient was significant in the communications and control equation, and it had a negative sign, indicating use of fewer communications and control technologies in the largest urban areas. Plant characteristics were generally significant, as they were in the model for use of all technologies. Plant size, military specifications, and fabrication were significant in each equation. The multiplant dummy was not significant for design and engineering technologies, but had a positive effect on use of fabrication and machining and communications and control technologies. The largest magnitude of the multiplant variable was on communications and control, reflecting the need for communications in larger multiplant firms. The only location characteristic significant in all three equations was percent minority population, indicating that, for whatever reason, plants with more technologies tend not to locate in areas with substantial minority population. Labor force age had a negative association with fabrication-machining and communications and control technologies. Schooling had a positive effect only on use of communications and control technologies. The location quotient was nonsignificant in each equation. Two-year and four-year college dummies were not significant in any of the equations.

I estimated nonmetro and metro models of total technology use to investigate the potentially different effects of plant and location characteristics on metro and nonmetro plants (table 6). Plant characteristics were important for both metro and nonmetro specifications, but only two location characteristics were significant for metro plants and none were significant for nonmetro plants. Beale code variables were not significant in the nonmetro model, indicating no difference among nonmetro locations of varying degrees of ruralness. However, the core metro variable had a significant negative coefficient in the metro model, indicating that large urban areas had slightly lower technology use, holding other characteristics constant. Plant age, military specifications, fabrication, multiplant, and plant size were significant in both equations. Magnitudes of the effects are similar, except for the plant age effect, which is much stronger for nonmetro plants. The oldest plants in nonmetro areas used 0.81 fewer technologies than the newest plants, about twice the differential between new and old metro plants. Schooling, labor force age, and percent minority population were significant in the full model, but labor force age was not significant in either model in table 6, and schooling and minority population were significant only for metro plants. Schooling and minority population effects apparently were valid only in metro areas. These results are consistent with the means shown in figures 8 and 9. The labor force age effect in the full model may have been picking up differences between rural and urban locations. Regional effects show that, among nonmetro plants, technology use was highest in the Mountain, Mid-Atlantic, East North Central, West North Central, and East South Central regions. The positive coefficient for the nonmetro Mountain region is surprising, because the mean value for that region was one of the lowest shown in figure 7. There was less difference among metro regions, with higher technology use observed in the East South Central, Mountain, and East North Central regions. In both models, the regional coefficients had positive coefficients, suggesting that technology use tended to be lowest in the West South Central region--the excluded category in both models.

## Conclusions

This study compared technology use for a sample of metro and nonmetro manufacturing establishments in five industries. The comparisons show no difference in technology use between metro and nonmetro plants. The characteristics of a plant are a much more important determinant of technology use than a plant's location. In particular, technology use varies with plant size, whether or not the plant is part of a multiplant firm, the nature of the production process, and the plant's industry. A few location characteristics are associated with technology use. Plants tend to use more technologies in locations with higher levels of schooling, lower concentrations of minority population, and a younger labor force. Proximity to higher education institutions and specialization of the local economy are not related to technology use.

This study's results indicate that rural location is not a major barrier to diffusion of technology within a given industry. Modern communications technology and general integration of rural and urban economies apparently overcome the spatial barrier in the spread of technologies. The importance of size-related variables (plant size, multiplant status) suggests a couple of possibilities. First, it may mean that lack of financial capital in small companies to implement new technologies is a more important barrier than the geographic flow of information. Alternatively, these results may suggest that new technologies are more cost effective for large firms, due to fixed costs of acquiring information and implementing new technologies.

Manufacturing extension programs or subsidized credit for implementing new technologies should target smaller and single-unit manufacturing plants. This study suggests that targeting rural areas would not be an effective use of scarce resources. The results seem to justify targeting assistance to urban communities with concentrations of minority population, but minority population does not seem to be a major factor in nonmetro areas.

In general, the level of education in a community affects its economic competitiveness, but this result does not seem to hold for nonmetro areas. I find a positive association between the level of schooling and technology use in metro areas, but no effect in nonmetro areas. This result is strikingly similar to other research that found a lower rate of return to education in rural areas than in urban areas (Greenberg, Swaim, and Teixeira; Kusmin). The more important effect may be in attracting industry, as half of the sample used in this study were located in metro counties in the highest schooling quartile.

The results of this study seem to conflict with Kusmin's study of computer use by individual workers that found a gap of 26 percent between metro and nonmetro rates of computer use. The two studies may be consistent, however. The present study included only a limited range of manufacturing industries, and these were among the more technology-intensive industries. This study's results show that rural location is not a barrier to the spread of technology *within a narrow range of industries*. The industries that are more common in rural areas, such as food processing, textiles and apparel, and lumber and wood products, were not included in this study. A rural-urban "technology gap" may still exist due to concentration of technology-intensive industries in urban centers and concentration of low-tech industries in rural locations. This would be consistent with the product-industry cycle theory of regional development, whereby innovative fast-growing industries with a need for flexibility locate in urban centers where information contacts are plentiful, while more mature industries specializing in routine production tasks locate in rural areas where production costs may be lower. Note that Kusmin is able to account for most of the metro-nonmetro gap by differences in occupation mix and education. A broader view of rural-urban technology comparison would also consider nonmanufacturing industries, especially service industries (OECD), which are heavily concentrated in urban areas.

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## Appendix: Count Data Regressions

As a general indicator of the degree of technology use by plants in the sample, I estimated a regression model that explains cross-sectional variation in the number of technologies per manufacturing plant.

Let $N_{jk}$ represent the number of technologies used by manufacturing plant j at location k, taking on integer values ranging from 0 to 17. Poisson regression is appropriate for count data where the dependent variable takes on discrete non-negative integer values (Cameron and Trivedi; Harris et al.; Maddala, p. 51). The variable $N_{jk}$ is assumed to be drawn from a Poisson distribution with parameter $\lambda_{jk}$. The probability that the number of "successes" equals n can be written as,

$$Prob\ (N_{jk} = n) = e^{-\lambda_{jk}} \frac{\lambda_{jk}^{n}}{n!}, \qquad n = 0,1,2,...,17. \tag{1}$$

The parameter $\lambda_{jk}$ is determined by characteristics of the plant and its location, according to:

$$\lambda_{jk} = a_0 + X_j a_1 + Z_k a_2, \tag{2}$$

where Xj is a vector of characteristics of plant j, $Z_k$ is a vector of characteristics of location k, $a_0$ is a constant, and $a_1$ and $a_2$ are vectors of coefficients to be estimated. The parameters $a_m$ can be estimated through maximum likelihood (Maddala).

A problem with the Poisson specification is the assumption that the mean and variance of the dependent variable are both equal to $\lambda_{jk}$ (Harris et al.; Greene). Overdispersion of the data, when the variance of the dependent variable exceeds its conditional mean, means that the Poisson model will yield consistent estimates of the parameters, but standard errors are biased downward (Gourieroux et al.). When overdispersion is present, the negative binomial model, a generalization of the Poisson model, is appropriate. The negative binomial model is specified by adding a stochastic term, ε to equation 2:

$$\lambda_{jk} = a_0 + X_j a_1 + Z_k a_2 + \varepsilon, \tag{3}$$

where exp(ε) has a gamma distribution with mean 1 and variance α (Cameron and Trivedi; Greene). This specification allows for overdispersion. The parameters, $a_m$ , are estimated with maximum likelihood using LIMDEP econometric software (Greene). The parameters do not have a direct interpretation as measures of effects on N of a change in the explanatory variables. For ease of presentation, the tables report only t-values and the derivatives, or marginal effects, computed from the coefficients and evaluated at the means.

## Explanation of terms

**Computer-Aided Design (CAD) and/or Computer-Aided Engineering (CAE).** Use of computers for drawing and designing parts or products and for analysis and testing of parts or products.

**Computer-Aided Manufacturing (CAM).** Use of CAD output for controlling machines used to manufacture the part or product.

**NC/CNC Machine.** A single machine either numerically controlled (NC) or computer numerically controlled (CNC) with or without automated materials-handling capabilities. NC machines are controlled by numerical commands, punched on paper or plastic mylar tape, while CNC machines are controlled electronically through a computer residing in the machine.

**Flexible Manufacturing Cell (FMC).** Two or more machines with automated materials-handling capabilities controlled by computers or programmable controllers, capable of single path acceptance of raw material and single path delivery of finished product.

**Flexible Manufacturing System (FMS).** Two or more machines with automated materials-handling capabilities controlled by computers or programmable controllers, capable of multiple path acceptance of raw material and multiple path delivery of finished product. An FMS may also be comprised of two or more FMC's linked in series or parallel.

**Materials-Working Laser.** Laser technology used for welding, cutting, treating, scribing, and marking.

**Pick and Place Robot.** A simple robot with one, two, or three degrees of freedom, which transfers items from place to place by means of point-to-point moves.

**Other Robots.** A reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized device through variable programmed motions for the performance of repetitive tasks, such as cutting, welding, drilling, or painting.

**Automatic Storage and Retrieval System (AS/RS).** Computer-controlled equipment providing for the automatic handling and storage of materials, parts, subassemblies, or finished products.

**Automatic Guided Vehicle System (AGVS).** Vehicles equipped with automatic guidance devices programmed to follow a path that interfaces with work stations for automated or manual loading and unloading of materials, tools, parts, or products.

**Programmable Controller.** A solid state industrial control device that has programmable memory for storage of instructions.

Source: U.S. Dept. Commerce, Bureau of Census and Baldwin, Diverty, and Sabourin.

Table 1--Rates of technology use by metro and nonmetro manufacturing plants, 1993

| Technology | Nonmetro | Metro | Difference |
|---|---|---|---|
| | *Percent of establishments* | | |
| **Design and engineering** | | | |
| CAD/CAE | 59.7 | 58.4 | 1.3 |
| CAD/CAM to control mfg. machines | 23.3 | 26.3 | *-3.0* |
| Digital CAD output used in procurement | 9.5 | 11.5 | *-1.5* |
| **Fabrication/machining and assembly** | | | |
| Numerically controlled machines | 48.5 | 47.0 | *1.5* |
| Flexible manufacturing cells | 16.9 | 11.9 | *5.0* |
| Materials working lasers | 4.4 | 5.2 | *-0.8* |
| Pick and place robots | 12.0 | 8.0 | *4.0* |
| Other robots | 8.4 | 4.1 | *4.3* |
| **Automated material handling** | | | |
| Automatic storage and retrieval systems | 2.1 | 2.7 | *-0.6* |
| Automatic guided vehicle systems | 1.4 | 1.0 | *0.4* |
| **Sensor based inspection/testing equipment** | | | |
| Inspection/testing for incoming materials | 10.3 | 9.9 | 0.4 |
| Inspection/testing for final product | 12.6 | 12.7 | -0.1 |
| **Communications and control** | | | |
| LAN for technical data | 26.6 | 29.4 | *-2.8* |
| LAN for factory use | 21.4 | 22.2 | -0.8 |
| Computers used for control--factory floor | 21.3 | 17.1 | *4.2* |
| Intercompany network | 38.4 | 28.6 | *9.8* |
| Programmable controllers | 27.9 | 26.6 | *1.3* |

Note: Italics indicate significant difference at the .05 level.

Source: USDA, Economic Research Service based on 1993 Survey of Manufacturing Technology weighted for stratification.

Table 2--Mean number of technologies used, by 3-digit SIC industry, nonmetro and metro plants, 1993

| Industry | SIC | Nonmetro | Metro | Difference |
|---|---|---|---|---|
| | | | *Number* | |
| Electrical industrial apparatus | 362 | 5.7 | 4.0 | 1.7 |
| Engines and turbines | 351 | 5.7 | 5.8 | -0.1 |
| Guided missiles, space vehicles, and parts | 376 | 5.4 | 5.6 | -0.2 |
| Measuring and controlling devices | 382 | 5.0 | 3.4 | 1.6 |
| Aircraft and parts | 372 | 4.8 | 5.0 | -0.2 |
| Electric distribution equipment | 361 | 4.7 | 3.6 | 1.1 |
| Household audio and video equipment | 365 | 4.5 | 3.1 | 1.4 |
| Household appliances | 363 | 4.4 | 4.1 | 0.3 |
| Electric lighting and wiring | 364 | 4.4 | 2.6 | 1.7 |
| Search and navigation equipment | 381 | 4.4 | 4.6 | -0.2 |
| Metalworking machinery | 354 | 4.3 | 4.1 | 0.2 |
| Photographic equipment and supplies | 386 | 4.3 | 2.8 | 1.5 |
| Watches, clocks, watch cases, and parts | 387 | 4.3 | 2.3 | 1.9 |
| Ordnance and accessories, nec | 348 | 4.3 | 4.5 | -0.3 |
| Metal forgings and stampings | 346 | 4.2 | 3.2 | 1.1 |
| Refrigeration and service machinery | 358 | 4.1 | 3.0 | 1.1 |
| Motorcycles, bicycles, and parts | 375 | 4.1 | 2.3 | 1.8 |
| General industrial machinery | 356 | 4.0 | 3.3 | 0.8 |
| Electronic components and accessories | 367 | 3.9 | 3.9 | -0.0 |
| Communications equipment | 366 | 3.9 | 4.2 | -0.3 |
| Motor vehicles and equipment | 371 | 3.8 | 3.9 | -0.0 |
| Miscellaneous fabricated metal products | 349 | 3.8 | 2.8 | 1.0 |
| Computer and office equipment | 357 | 3.7 | 3.8 | -0.1 |
| Cutlery, handtools, and hardware | 342 | 3.7 | 3.1 | 0.5 |
| Misc. electrical equipment and supplies | 369 | 3.4 | 3.1 | 0.3 |
| Plumbing and heating, ex. electric | 343 | 3.3 | 2.4 | 0.9 |
| Industrial machinery, nec | 359 | 3.3 | 3.4 | -0.2 |
| Railroad equipment | 374 | 3.2 | 3.6 | -0.5 |
| Construction and related machinery | 353 | 3.1 | 2.8 | 0.3 |
| Medical instruments and supplies | 384 | 2.9 | 3.5 | -0.6 |
| Special industry machinery | 355 | 2.9 | 3.1 | -0.2 |
| Farm and garden machinery | 352 | 2.6 | 2.6 | -0.0 |
| Metal cans and shipping containers | 341 | 2.6 | 3.0 | -0.4 |
| Screw machine products, bolts, etc. | 345 | 2.3 | 2.9 | -0.6 |
| Fabricated structural metal products | 344 | 2.3 | 2.2 | 0.1 |
| Metal services, nec | 347 | 1.7 | 1.3 | 0.3 |
| Miscellaneous transportation equipment | 379 | 1.5 | 2.1 | -0.6 |
| Ship and boat building | 373 | 1.3 | 0.9 | 0.4 |
| Ophthalmic goods | 385 | 0.5 | 2.8 | -2.4 |

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

Note: Industries ranked by nonmetro technology use.

nec = not elsewhere classified.

Table 3--Mean values, metro and nonmetro plants, 1993

| Variable | Nonmetro | Metro |
|---|---|---|
| Number of technologies used: | | |
| All technologies | 3.71 | 3.48 |
| Design and engineering technologies | 1.00 | 1.04 |
| Fabrication and machining | .97 | .82 |
| Automated material handling | .04 | .04 |
| Communication and control | 1.46 | 1.34 |
| | | |
| Core metro county | | .61 |
| Fringe metro | | .04 |
| Medium metro | | .26 |
| Small metro | | .08 |
| Urbanized nonmetro | .34 | |
| Less urbanized nonmetro, adjacent to metro | .36 | |
| Less urbanized nonmetro, not adjacent | .30 | |
| | | |
| Log plant employment | 4.39 | 4.13 |
| Multi-plant firm (yes=1, no=0) | .48 | .36 |
| Products built to military specifications (yes=1, no=0) | .30 | .37 |
| Fabrication (yes=1, no=0) | .83 | .76 |
| Plant age < 5 years | .08 | .13 |
| Plant age 30 years or more | .26 | .24 |
| | | |
| Commuting zone location quotient | 1.78 | 1.40 |
| Commuting zone average years of schooling | 12.69 | 13.09 |
| Percent working-age pop over age 55 | 15.16 | 13.44 |
| Percent minority population | 9.31 | 19.10 |
| Public 2-year college present in county (yes=1, no=0) | .33 | .84 |
| Public 4-year college present in county (yes=1, no=0) | .16 | .71 |
| | | |
| Sample size | 1,370 | 6,031 |

Weighted with sample weights.

Source: USDA, Economic Research Service based on data from U.S. Dept. Commerce, Bureau of the Census, 1993 Survey of Manufacturing Technology, unpublished data.

Table 4. Plant and location characteristics affecting technology use

| Variable | Marginal effect | T-value |
|---|---|---|
| Log output price | -.003 | (-.25) |
| Plant age <5 years | .e | |
| 5 - 15 years | -.070 | (-.73) |
| 16 - 30 years | -.294* | (-2.99) |
| over 30 years | -.434* | (-4.25) |
| Military specifications | .488* | (8.32) |
| Fabrication | .981* | (14.37) |
| Multiplant firm | .601* | (9.65) |
| Log plant employment | 1.344* | (55.44) |
| | | |
| Core metro | -.201 | (-1.29) |
| Other metro | -.048 | (-.35) |
| Urbanized nonmetro | -.168 | (-1.07) |
| Less urbanized nonmetro adjacent | -.210 | (-1.33) |
| Less urbanized nonmetro nonadjacent | .e | |
| | | |
| Industry location quotient | .010 | (.51) |
| Average years of schooling | .245* | (2.60) |
| Four-year college present | -.007 | (-.10) |
| Two-year college present | .041 | (.55) |
| Labor force age | -.048* | (-2.55) |
| Percent minority population | -.011* | (-4.30) |
| | | |
| Three-digit SIC dummies | yes | |
| Region dummies | yes | |
| | | |
| $\alpha$** | .091 | (17.19) |
| N | 7,401 | |
| Chi-square | 427.7 | |
| lnL | -16982 | |

Estimates shown are obtained from negative binomial regressions estimated with LIMDEP. Marginal effects evaluated at mean values. e = excluded categorical dummy variable.

* = significantly different from zero at .05 level. **Dispersion parameter shown rather than marginal effect. NA = not applicable.

Source: USDA, Economic Research Service based on data from U.S. Dept. Commerce, Bureau of the Census, 1993 Survey of Manufacturing Technology, unpublished data.

Table 5--Effects of selected variables on use of three technology types, 1993

| Variable | Technology type: Design and engineering (Range: 0-3) | | Fabrication and machining (Range: 0-5) | | Communications and control (Range: 0-5) | |
|---|---|---|---|---|---|---|
| Plant age < 5 years | .e | | .e | | .e | |
| 5-15 years | -.035 | (-.68) | .024 | (.58) | -.078 | (-1.45) |
| 16-30 years | -.049 | (-.92) | -.041 | (-.98) | -.155* | (-2.80) |
| over 30 years | -.081 | (-1.45) | -.065 | (-1.51) | -.233* | (-4.06) |
| Military specifications | .105* | (3.54) | .080* | (3.85) | .207* | (6.62) |
| Fabrication | .285* | (7.52) | .529* | (18.19) | .155* | (4.04) |
| Multiplant firm | .031 | (.92) | .093* | (3.72) | .331* | (9.38) |
| Log plant employment | .236* | (20.39) | .348* | (42.85) | .599* | (44.45) |
| Core metro | .035 | (.46) | -.028 | (-.56) | -.167* | (-2.13) |
| Other metro | .027 | (.39) | -.017 | (-.37) | -.028 | (-.39) |
| Urbanized nonmetro | -.042 | (-.51) | -.016 | (-.31) | -.103 | (-1.26) |
| Less urbanized adjacent | -.015 | (-.18) | -.037 | (-.70) | -.113 | (-1.35) |
| Less urbanized nonadjacent | .e | | .e | | .e | |
| Location quotient | .010 | (1.06) | -.011 | (-1.53) | .011 | (1.08) |
| Average years of schooling | .044 | (.93) | .017 | (.51) | .134* | (2.66) |
| Four-year college present | .023 | (1.05) | -.096 | (-.39) | .031 | (.83) |
| Two-year college present | -.041 | (-1.79) | .042 | (1.64) | -.046 | (-1.17) |
| Labor force age | -.008 | (-.84) | -.013* | (-1.93) | -.021* | (-2.05) |
| Percent minority population | -.0027* | (-2.20) | -.0038* | (-4.35) | -.0034* | (-2.61) |
| α*** | .0005 | (.97) | NA** | | .066* | (5.93) |
| N | 7401 | | 7401 | | 7401 | |
| Chi-square | 1324.3 | | 2777.5 | | 990.4 | |
| lnL | -8751.1 | | -8917.0 | | -11252.6 | |

The table shows marginal effects estimated with LIMDEP negative binomial regression evaluated at mean values, with t-values in parentheses. Results are shown for three dependent variables. Coefficients on intercept, three-digit industry dummy variables, regional dummies, and output price not shown.
* significant at .05. **Poisson regression results are presented because the negative binomial equation failed to converge. ***Dispersion parameter shown rather than marginal effect. e = excluded categorical dummy variable.

Source: USDA, Economic Research Service based on data from U.S. Dept. Commerce, Bureau of the Census, 1993 Survey of Manufacturing Technology, unpublished data.

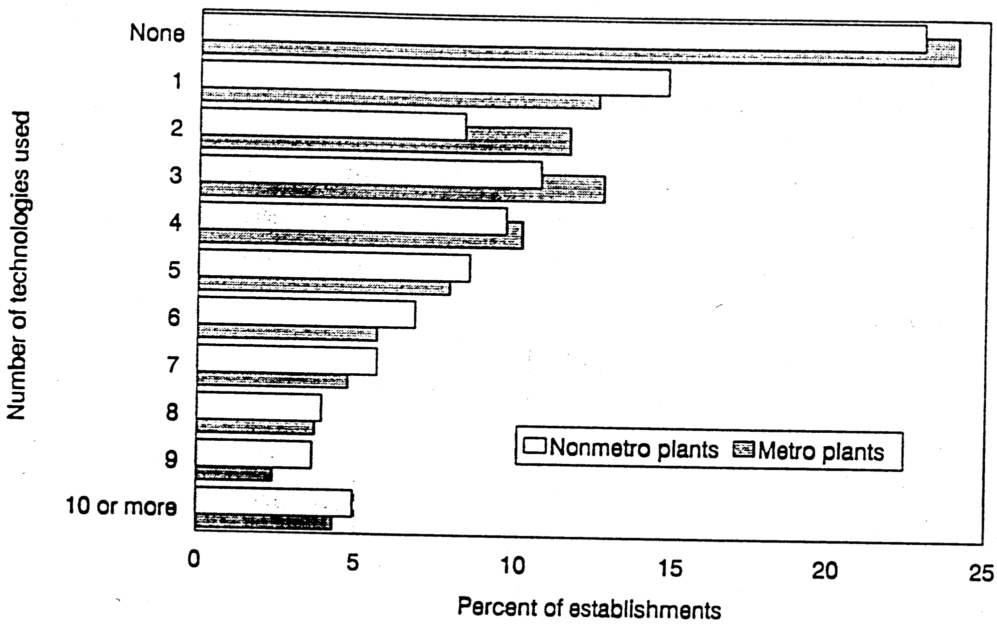
Table 6--Effects of selected variables on technology use in metro and nonmetro manufacturing plants

| Variable | Nonmetro plants: Marginal effect | Nonmetro plants: T-value | Metro plants: Marginal effect | Metro plants: T-value |
|---|---|---|---|---|
| Plant age < 5 years | .e | | .e | |
| 5-15 years | -.36 | (-1.43) | -.006 | (-.05) |
| 16-30 years | -.67* | (-2.76) | -.22* | (-1.99) |
| over 30 years | -.81* | (-3.22) | -.38* | (-3.41) |
| Military specifications | .45* | (3.38) | .49* | (7.44) |
| Fabrication | 1.13* | (7.07) | .96* | (12.66) |
| Multiplant firm | .54* | (3.73) | .62* | (9.00) |
| Log plant employment | 1.58* | (25.02) | 1.30* | (48.74) |
| Core metro | | | -.16* | (-2.00) |
| Other metro | | | .e | |
| Urbanized nonmetro | -.22 | (-1.32) | | |
| Less urbanized adjacent | -.17 | (-1.08) | | |
| Less urbanized nonadjacent | .e | | | |
| Industry location quotient | .020 | (.62) | -.007 | (-.30) |
| Average schooling | -.017 | (-.08) | .328* | (3.00) |
| Four-year college present | .090 | (.51) | -.037 | (-.49) |
| Two-year college present | -.038 | (-.27) | .083 | (.96) |
| Labor force age | -.056 | (-1.44) | -.039 | (-1.70) |
| Percent minority population | -.007 | (-1.30) | -.011* | (-3.72) |
| New England | .388 | (.97) | .157 | (.90) |
| Mid Atlantic | .824* | (2.51) | -.032 | (-.21) |
| East North Central | .854* | (3.23) | .371* | (2.87) |
| West North Central | .606* | (2.12) | .212 | (1.28) |
| South Atlantic | .260 | (.93) | .249 | (1.70) |
| East South Central | .525* | (1.96) | .526* | (2.98) |
| West South Central | .e | | .e | |
| Mountain | .996* | (2.37) | .471* | (2.44) |
| Pacific | .793 | (1.80) | .139 | (1.10) |
| α** | .042* | (4.15) | .096* | (16.12) |
| N | 1370 | | 6031 | |
| Chi-square | 27.1* | | 377.3* | |
| lnL | -3102 | | -13,827 | |

Dependent variable = number of technologies used. Estimated with LIMDEP negative binomial regression routine. Marginal effects evaluated at mean values. * significant at .05. **Dispersion parameter shown rather than marginal effect. e = excluded categorical dummy variable. Also included: intercept, Industry, Output price.

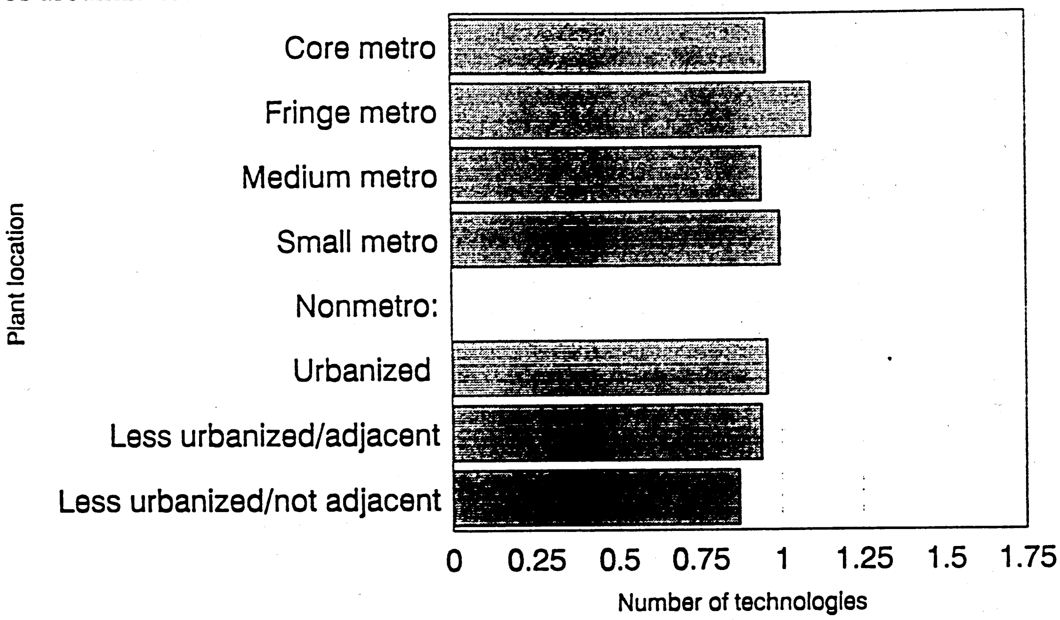
Source: USDA, Economic Research Service based on data from U.S. Dept. Commerce, Bureau of the Census, 1993 Survey of Manufacturing Technology, unpublished data.

**Figure 1**. Number of technologies used, by metro and nonmetro manufacturing plants



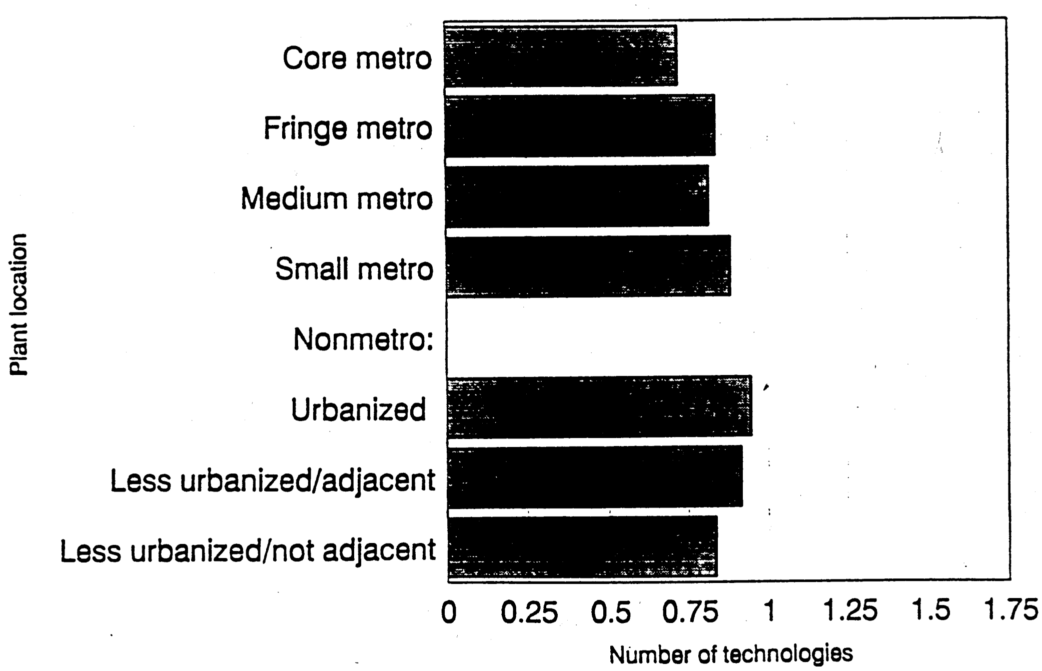

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology weighted for stratification.

**Figure 2.** Mean number of design and engineering technologies used, by degree of urbanization



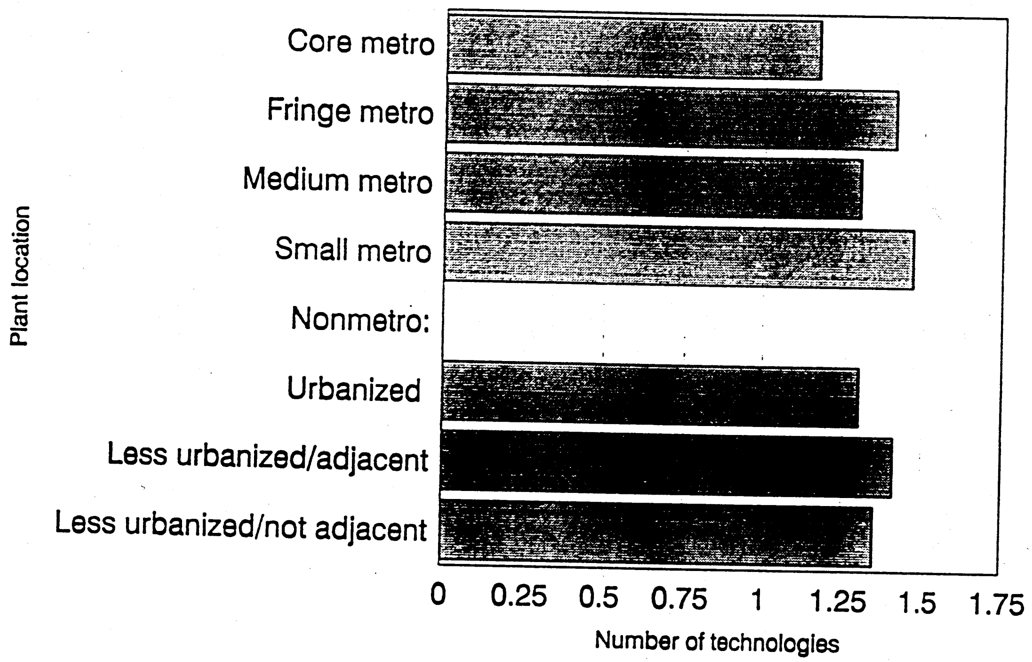

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 3.** Mean number of fabrication and machining technologies used, by degree of urbanization



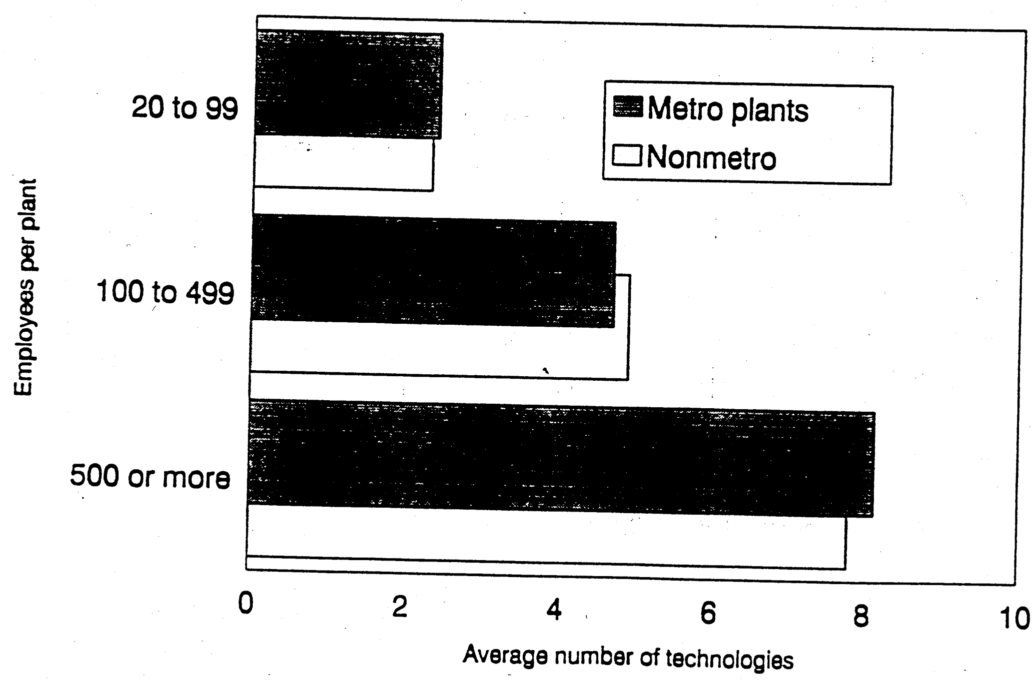

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 4**. Mean number of communication and control technologies used, by degree of urbanization



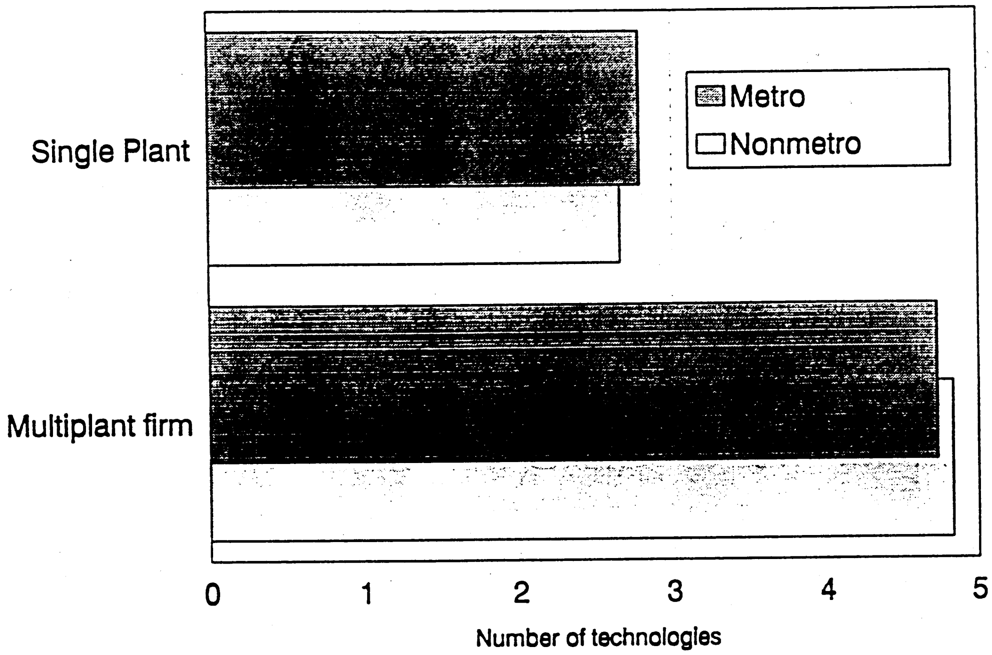

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 5**. Mean number of technologies used, by plant size, metro and nonmetro plants



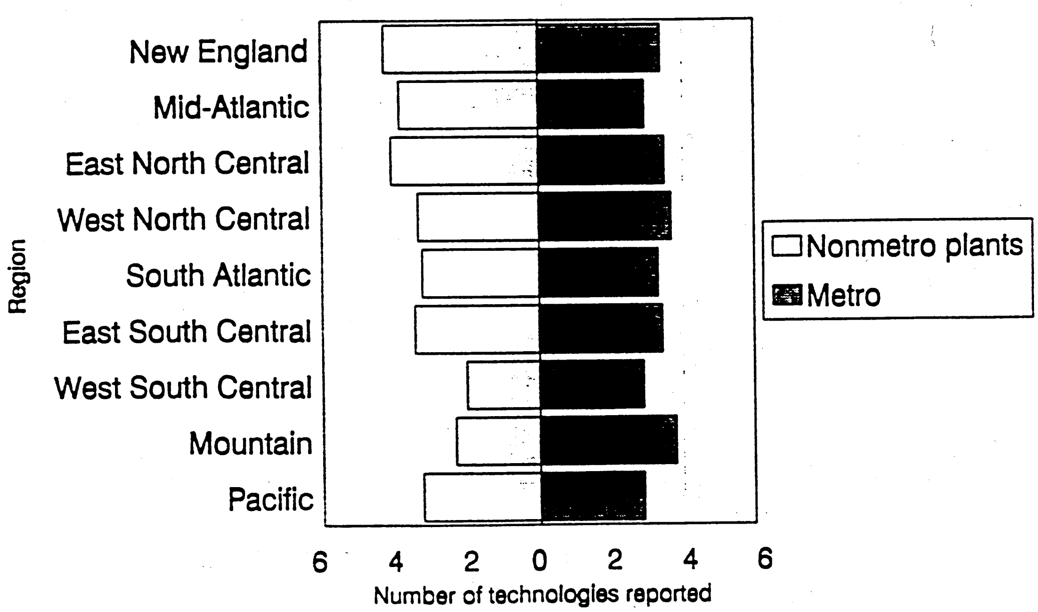

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 6.** Mean number of technologies used by multiunit status, metro and nonmetro plants



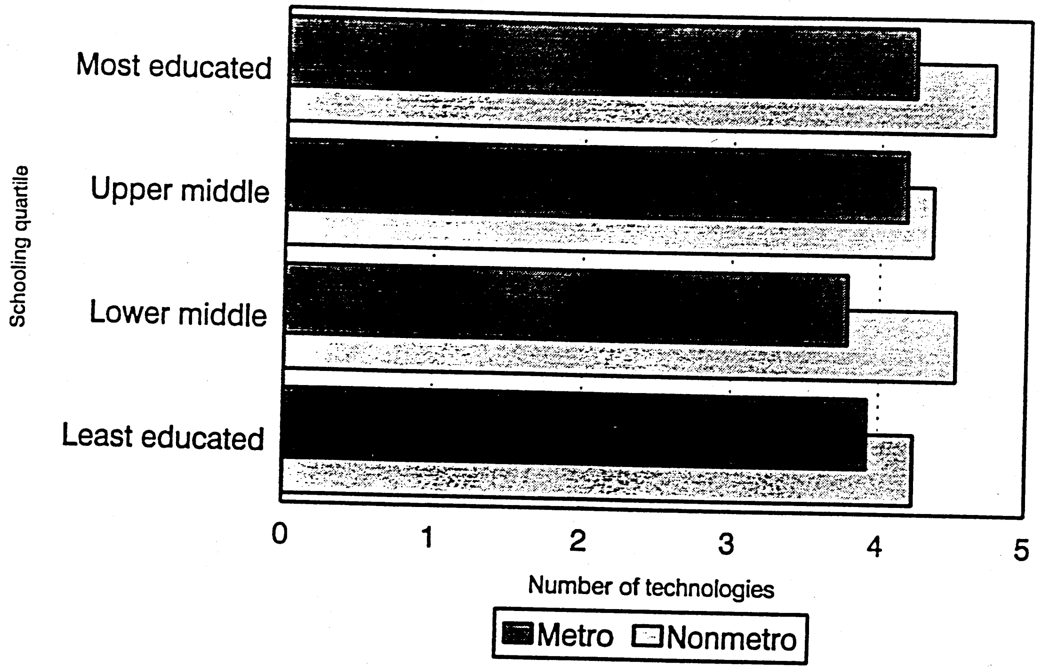

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 7.** Mean number of technologies used, by region, metro and nonmetro plants



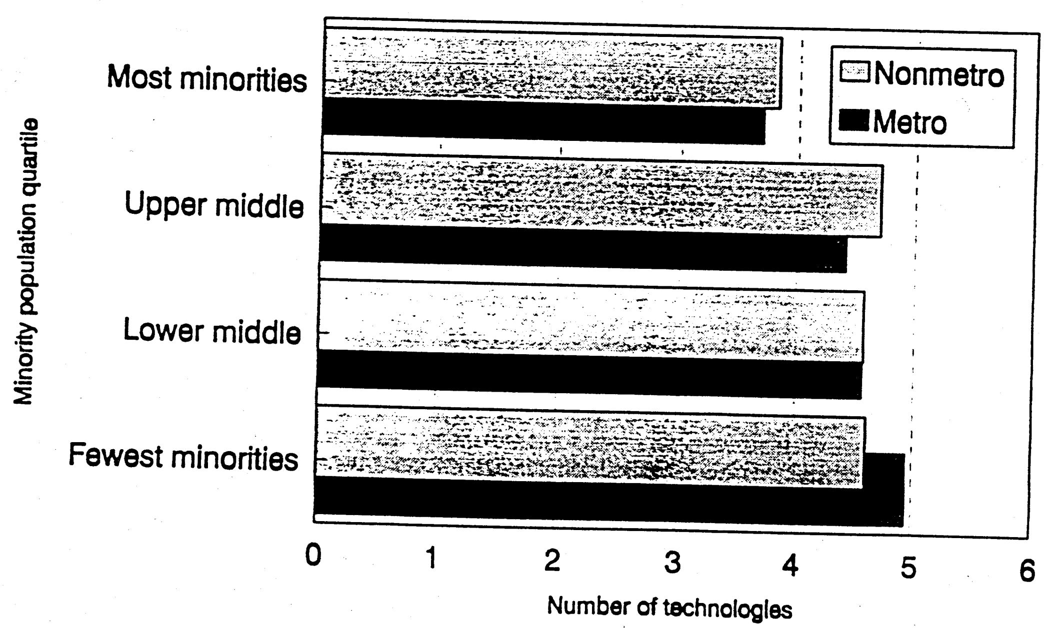

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 8.** Mean number of technologies used, by commuting zone schooling quartile, metro and nonmetro plants



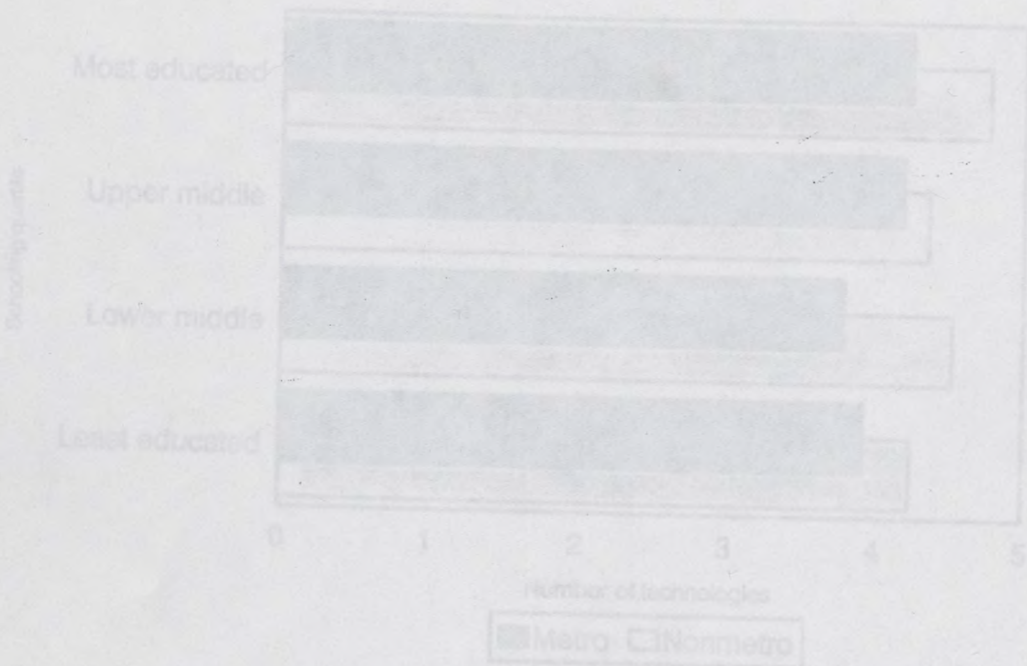

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

**Figure 9.** Mean number of technologies used, by percent minority population quartile, metro and nonmetro plants



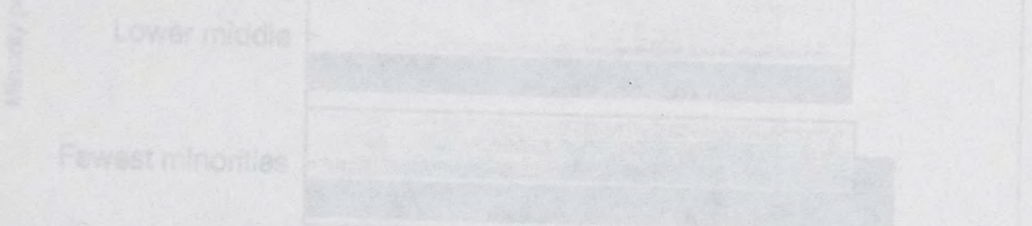

Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

Figure 8. Mean number of technologies used, by commuting zone schooling quartile, metro and nonmetro plants




Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.

Figure 9. Mean number of technologies used, by percent minority population quartile, metro and nonmetro plants




Source: USDA, Economic Research Service based on data from 1993 Survey of Manufacturing Technology data weighted for stratification.