The Influence of Location on Productivity: Manufacturing Technology in Rural and Urban Areas

S.A. Martin,
Richard McHugh, and S.R. Johnson

Working Paper 91-WP 83
November 1991

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011

S.A. Martin is a research associate, CARD; Richard McHugh is director of the Center for Economic and Management Research, University of South Florida; and S.R. Johnson is director of CARD and Charles F. Curtiss Distinguished Professor of Agriculture, Iowa State University.

The authors would like to thank the participants in the Center for Economic Studies seminar series for helpful comments. Special thanks go to Gary Stampley for data assistance.

Abstract

Policies to counter the growing discrepancy between economic opportunities in rural and urban areas have focused predominantly on expanding manufacturing in rural areas. Fundamental to the design of these strategies are the relative costs of production and productivity of manufacturing in rural and urban areas. This study aims to develop information that can be used to assess the productivity of manufacturing in rural and urban areas. Production functions are estimated in the meat products and household furniture industries to investigate selected aspects of the effect of rural, small urban, and metropolitan location on productivity. The results show that the effect of location on productivity varies with industry, size, and the timing of the entry of the establishment into the industry. While the analysis is specific to two industries, it suggests that development policies targeting manufacturing can be made more effective by focusing on industries and plants with characteristics that predispose them to the locations being supported.

The Influence of Location on Productivity:
Manufacturing Technology in Rural and Urban Areas

1. Introduction

The economic base for rural communities in the United States has continually declined as modern agricultural technologies have been adopted, the structure of agribusiness has changed, and rural populations have gained greater access to urban areas, all of which have strengthened the agglomeration economies of metropolitan locations. Policies to counter the growing discrepancy between economic opportunities in rural and urban areas have focused predominantly on expanding manufacturing in rural areas, in order to strengthen the rural export base (Otto, et al. 1989). Fundamental to the design of these strategies are the relative costs of production and productivity of manufacturing in rural and urban areas. With this information, particular manufacturing industries can be targeted more effectively, and more accurate judgments can be made regarding the magnitude of subsidies and other incentives required for stimulating rural manufacturing.

The present study was undertaken in order to develop information useful for assessing the productivity of manufacturing in rural and urban areas. The approach and analysis are made possible by a unique and newly available database derived from the Census of Manufactures and the Annual Survey of Manufactures. Two industries are analyzed: meat products (SIC 201) and household furniture (SIC 251). These industries have drawn heavily on raw materials from agriculture and forestry, and have been targets for "value added" initiatives for development of rural communities. Results show definite differences in productivity between rural and urban areas and point to possible interventions that might persuade manufacturers to favor rural location.

In section 2, descriptive information on the two manufacturing industries is summarized, providing a perspective for the analytical results. The urban-rural split of establishments in each industry is provided, and an overview of the structure of each industry is given. Section 3 describes the translog model used to approximate the direct production function, along with methods of estimation. Findings and hypothesis tests for urban and rural differences are provided in section 4. Output and price elasticities, elasticities of substitution, and total factor productivity are calculated from the estimated structural parameters. Factors that may be responsible for the observed differences in productivity (size, in particular) are explored in section 5. Concluding observations are provided in section 6, along with implications for rural development policy.

2. Rural-Urban Variation in the Meat Products and Household Furniture Industries

Obvious differences exist between the meat products and household furniture industries with respect to size, value added, and relative size of capital stock. After a brief description of the data and an explanation of the chosen distinction between rural and urban areas, possible implications of these differences for relative rural-urban productivity are explored.

Data

The data used in this study are extracted from the Longitudinal Research Database (LRD), which is maintained by the Center for Economic Studies at the U.S. Bureau of the Census. The LRD is a panel data set constructed by linking together individual establishment records from the Census of Manufactures (CM), which takes place every five years, and the Annual Survey of Manufactures (ASM). The Census of Manufactures is a complete enumeration of all manufacturing plants that had one or more persons employed at any time during the census year. Because the plant is the basic unit of observation, any firm that operates more than one plant is required to file separate reports for each plant. The plant-level data include labor, materials, and capital used in the production process; product and service output; location of the plant; and the legal form of organization of the owning firm. Each of the censuses from 1963 to 1982 contains between 300,000 and 350,000 manufacturing plants. A detailed explanation of the content and construction of the LRD can be found in McGuckin and Pascoe (1988).

For this study, we pool cross sections of the CM data for 1972, 1977, and 1982. Analysis was limited to eight midwestern states: Illinois, Iowa, Kansas, Minnesota, Nebraska, Missouri, South Dakota, and Wisconsin. Each of these states contains sizable rural areas, large metropolitan areas, and smaller nonmetropolitan urbanized areas. All have been significantly affected by the population shifts and decline generally experienced in rural areas over the last two decades. The meat products and household furniture industries were selected for their relatively even distribution of establishments between rural and urban areas.

Rural-Urban Distinction

Each establishment was assigned a Beale code according to the county in which it is located. Also known as rural-urban continuum codes, Beale codes were developed in 1975 and updated in 1983 and 1988. Beale codes form a classification scheme that provides a finer county-level rural-urban distinction than the traditional census metropolitan-nonmetropolitan breakdown of counties (Butler 1990). Metropolitan counties are distinguished by the population size of the Metropolitan Statistical Area (MSA) of which they are a part, with counties in MSA's with populations of one million or more divided based on whether they are central or fringe counties. Nonmetropolitan counties are classified according to the aggregate size of the urban population, and whether or not they are adjacent to an MSA. The list of Beale codes and their exact definitions are found in Butler (1990).

Throughout this paper, statistics are aggregated for selected groups of Beale codes referred to as urban classes. These groupings provide a more general picture of conditions in rural and urban economies. The Metropolitan class includes establishments in counties with assigned Beale codes of 0 through 3; the Small Urban class includes establishments in counties with Beale codes 4 and 5; the Rural class includes establishments in counties with Beale codes 6 through 9.

Industry Characteristics: Size and Productivity

The meat products industry includes four four-digit industries, but is dominated by the meat-packing industry, which represents about 57 percent of the total number of establishments and 82 percent of the nominal output in the industry. In the household furniture industry, both establishments and output are divided more evenly among the four largest of its four-digit industries. Table 1 provides a statistical summary of the size and productivity indicators for each industry by urban class. Several important differences between the industries are worth noting. The most obvious of the differences is size. In terms of nominal output, the average meat products establishment is ten times the size of the average household furniture establishment. The difference in size is less pronounced when size is defined in terms of total employment; meat products establishments employ, on the average, 2.5 times as many workers as household furniture establishments.

Another conspicuous difference between the two industries is the input mix used in the production process. Real output (nominal output deflated as described below) per production worker hour in meat products is almost three times that in the household furniture industry. The significantly higher level of capital per labor hour most likely accounts for some of this difference. Furthermore, the lower percentage of value added to meat products suggests a high level of materials input when compared to the household furniture industry.

Table 1 also suggests differences within the industries across urban classes. In both industries, the largest establishments are located in small urban areas, and the smallest establishments are in rural areas. Metropolitan meat products establishments have a higher capital labor ratio than their nonmetropolitan counterparts, but this ratio varies less across locations in the furniture industry. Output per production worker hour is highest in metropolitan establishments in the meat products industry; in the household furniture industry, it is highest in small urban establishments. Although this is a crude measure of the relative productivity of plants in different areas, similar findings result when a more sophisticated measure, relative multifactor productivity, is employed.

The two industries for which production functions will be estimated exhibit important differences in technology, as evidenced by differences in the average size of the establishments, capital and output per production worker hour, and value added as a percentage of total output. These differences are likely to contribute to results regarding the relative productivity of establishments in rural, small urban, and metropolitan locations. These factors will be explored further in interpretation of our results and suggestions for further research.

3. Production Function and Estimation Methods

The Longitudinal Research Database details the outputs and inputs used by each establishment in the industry. This level of detail facilitates direct estimation of the production function, given the assumption of endogenous output quantities (Berndt, 1990). In this section, a three-factor translog production function is specified, and the cost-share equations are derived to complete the three-equation system to be estimated. Notes on variable definitions lead to an explanation of the estimation procedures.

Model Specification

Consider a production process in which outputs and inputs are related by the function F:

$$Q = F(X;Z),$$

where $\underline{X}$ is a vector of inputs and $\underline{Z}$ is a vector of other variables that may affect output. If F is homogeneous of degree λ in the input vector, then

$$F(X;Z)r^{\lambda} = F(rX;Z).$$

Assuming cost minimization, the cost share equation of input i is derived by dividing the log marginal product of the input by the returns-to-scale parameter, λ.

For estimation, a specific functional form must be chosen for F. To allow for the possibility of elasticities that vary across pairs of factors, a flexible functional form was desired. The transcendental logarithmic (translog) form has received a great deal of attention and application in empirical work. While it shares second-order approximation properties with other flexible forms, the translog has the fewest free parameters, and estimates of the parameters tend to converge more quickly than estimates from other forms (Nguyen & Reznek 1991). Furthermore, Guilkey, Lovell, and Sickles (1983) have compared the results of estimation of a known technology for the translog, the generalized Leontief, and the generalized Cobb Douglas and have found the translog as reliable or more reliable than the other two forms. While the translog suffers from some limitations with respect to theoretical consistency (i.e., it cannot represent globally convex isoquants), tests of theoretical consistency within the relevant domain often produce satisfactory results.

Initially, a three-factor translog production function was specified, including capital, labor, and materials in the production of output Q. In addition, a qualitative variable representing the location of the establishment in a rural or urban location was included:

URB = 1 if establishment is located in an urban county;
0 otherwise ;

RURAL = 1 if the establishment is located in a rural county;
0 otherwise.

A definition of urban establishment was selected by testing the models for their sensitivity to different definitions. In the first definition, only establishments in counties that are part of an MSA (Beale codes 0, 1, 2, and 3) were classified as urban. In the alternate definition, any establishment located in a county with an urban population of 20,000 or more (Beale codes 0 through 5) was considered urban.

Initial estimation showed that the results were sensitive to which definition of urban was chosen. In particular, the coefficients of the parameters of the first- and second-order location terms changed slightly when the definition of urban was changed for both industries; in the meat industry, the coefficients of the first-order term and one second-order terms went from being statistically insignificant to significant when the definition was changed from the first to the alternate.

These results favored a decision to estimate a production function in which establishments were classified into one of three categories:

METRO = 1 if the establishment is located in a metropolitan county (Beale codes 0 to 3)

0 otherwise

SURB = 1 if the establishment is located in a nonmetropolitan county with urban population of 20,000 or more (Beale codes 4 or 5)

0 otherwise

RURAL = 1 if the establishment is located in a rural county

0 otherwise

In this case, the specification of the translog production function is

$$\begin{aligned} lnQ &= \alpha_o + \alpha_{u1}METRO + \alpha_{u2}SURB + \alpha_l lnL + \alpha_k lnK + \alpha_m lnM \\ &+ .5\alpha_{ll}(lnL)^2 + .5\alpha_{kk}(lnK)^2 + .5\alpha_{mm}(lnM)^2 \\ &+ \alpha_{lk}(lnL * lnK) + \alpha_{lm}(lnL * lnM) + \alpha_{km}(lnK * lnM) \\ &+ \alpha_{u1L}(lnL * METRO) + \alpha_{u1k}(lnK * METRO) + \alpha_{u1m}(lnM * METRO) \\ &+ \alpha_{u2l}(lnL * SURB) + \alpha_{u2m}(lnm * SURB) + \alpha_{u2k}(lnK * SURB) \;. \end{aligned}$$

The cost shares are

$$S_l = \frac{1}{\lambda}\left[\alpha_L + \alpha_{ll} lnL + \alpha_{lk} lnK + \alpha_{lm} lnM + \alpha_{u1l} METRO + \alpha_{u2l} SURB\right],$$

$$S_K = \frac{1}{\lambda}\left[\alpha_k + \alpha_{kk} lnK + \alpha_{lk} lnL + \alpha_{km} lnM + \alpha_{u1k} METRO + \alpha_{u2k} SURB\right],$$

$$S_M = \frac{1}{\lambda}\left[\alpha_m + \alpha_{mm} lnM + \alpha_{ml} lnL + \alpha_{mk} lnK + Au1mMETRO + \alpha_{u2m} SURB\right].$$

Homogeneity of degree λ requires the following restrictions on both systems:

$$\alpha_k + \alpha_l + \alpha_m = \lambda,$$

$$\alpha_{kk} + \alpha_{kl} + \alpha_{km} = 0,$$

$$\alpha_{ll} + \alpha_{kl} + \alpha_{ml} = 0,$$

$$\alpha_{mm} + \alpha_{ml} + \alpha_{mk} = 0.$$

Rather than estimating the production function alone, the production function and share equations were estimated as a simultaneous system, in order to increase the degrees of freedom without adding to the number of free parameters (Berndt 1990). Because only two of the three equations in the cost share system are linearly independent (the sum of the cost shares always equals 1), one of the equations must be dropped from the estimation model. In general, maximum likelihood estimates of the system will be invariant to the choice of which of the share equations are estimated directly. However, this is not the case for the Zellner Efficient Estimator (ZEF) employed here, in which the first-round estimate of the disturbance covariance matrix is based on a stacked equation system with symmetry restrictions imposed. In this case, ZEF parameter estimates may vary on the basis of which share equations are directly estimated (Berndt 1990). However, because the capital stock and capital cost measures are considered the least reliable element of the Census data (see below for a summary of problems of capital stock and capital cost measurement), it is common practice when using this data to drop the capital cost-share equation (Nguyen and Reznek 1991).

Variable Construction

The inputs and outputs are calculated separately from the LRD for each manufacturing establishment. The LRD data are supplemented by deflators from the Bureau of Economic Analysis, as well as by capital cost measures from the Bureau of Labor Statistics.

Output. Output is defined at the plant level as the total value of shipments, adjusted for changes in inventories of finished goods and work-in-process.

Labor. The Census of Manufactures provides data on the number of production and nonproduction employees, production and nonproduction salaries and wages, and, for production employees, the number of total hours actually worked. Total hours is a more accurate measure of actual labor input than the number of employees; however, because data on the number of hours for nonproduction workers is not available, some estimate must be developed.

The first option is to assume a 2000 hour work-year for nonproduction employees. The second is to calculate production worker-equivalent hours by assuming that relative wages are proportional to marginal productivity. The average production worker wage rate is the ratio of total production worker wages to total production worker hours. Total plant worker hours then can be estimated as the ratio of total wages for all workers divided by the average production worker wage rate.

Two factors motivated a decision to use the average production worker wage rate. First, the number of nonproduction employees is collected on March 12; fluctuations occurring throughout the year are not observed. However, total wages are reported for the entire year, and will reflect these fluctuations. Furthermore, many nonproduction workers may work part-time; assuming a 2000 hour work-year for every worker clearly overestimates some actual contributions.

Materials. Total materials consumed consists of four components: parts and materials, electricity, contract work, and fuels. All materials data are adjusted for inventory, reflecting the actual value of materials used in the production process. To make the materials measure comparable over time, it is deflated as described below.

Capital. Capital services are ideally measured as machine hours per year, with adjustments for the vintage of machinery and the intensity of its use. For most practical applications, the common practice is to use the perpetual inventory method to deflate the value of the gross capital stock, and then to adjust this by a utilization rate (Usher 1980). In this study, the capital input is the gross capital stock, which is the sum of structures and machinery at the end of the year (if this figure is zero we substitute beginning of year capital stock).

This measure of capital input is clearly imperfect; several problems are worth noting. First, buildings and machinery are imputed for firms that are not a part of the ASM sample, using industry averages; second, the combination of machinery and buildings into one measure implies that they are homogenous factors; clearly, arguments could be made against this. Third, no adjustment is made for vintage or intensity of use; fourth, capital is recorded at its book value.

Unfortunately, these problems are unavoidable, given the constraints on the data and the desired sample. Perpetual inventory methods of capital measurement are available only for firms in the ASM sample that are observed continually from 1972 to 1982. This would severely limit the data on small establishments. However, concerns about the capital measurement problem are mitigated by studies suggesting that gross capital stock may be a reasonable approximation of real capital input (Doms 1991).

Deflators. Real output and materials are derived from nominal measures by applying a set of deflators developed by the Bureau of Economic Analysis (BEA). The output deflator is based on product price indices from the Bureau of Labor Statistics, supplemented by a few specialized deflators for military goods from the government division of the BEA. A price index for each seven-digit product code is weighted by the share of that product in the industry's production. The materials deflator was created by averaging together price deflators for 529 inputs, using as weights the relative size of each industry's purchases of that input in the Census Bureau's input-output tables.

Cost Shares. Total labor cost includes salary and wages and supplemental labor costs. The cost of capital is determined by multiplying structures and equipment by their separate rental measures for the given year, as developed by the Bureau of Labor Statistics. The total cost of production is the sum of labor, capital and materials cost. The share for each input is the ratio of input cost to total production cost.

Estimation Procedures

The production function was estimated jointly with the labor and materials share equations as a simultaneous system using the seemingly unrelated regressions method (Zellner 1962). Three hypothesis tests were performed to test the existence of location effects: a test that all location parameters were jointly equal to zero, a test that metropolitan location parameters were equal to zero, and a test that small urban location parameters were equal to zero. If these hypotheses were accepted, the model was tested for Cobb-Douglas technology.

Our tests are based on the Gallant-Jorgenson analog of the likelihood ratio test (Gallant and Jorgenson 1979). The test statistic is

$$T^{o} = N * S(\alpha,V)_{r} - N * S(\alpha,V)_{u} ,$$

where S_r and S_u are the minimum values of the objective functions of the restricted and unrestricted models, respectively, and N is the number of observations. T^o is distributed chi-squared with degrees of freedom equal to the number of restrictions. The estimated disturbance covariance matrix from the unrestricted model was forced on the restricted models, as required for the hypothesis tests.

4. Empirical Results

Estimation results revealed that the location of an establishment was associated with production technology and productivity differences. These results are confirmed in the hypothesis tests, the parameter estimates, and the analysis of multifactor productivity. Some consequences of these technology differences are illustrated by variations in elasticities across industries and locations.

Hypothesis Tests

Three hypothesis tests were performed on groups of parameters for each industry: no effects for metropolitan location, no effects for small urban location, and no location effects. In each case, the T^{o} statistic was sufficiently large to reject the null hypothesis.

Parameter Estimates

Parameter estimates for the three-factor translog production function are shown in table 2. For both industries, all first- and second-order terms are significantly different from zero. The returns-to-scale parameter, λ, shows significant deviation from constant returns only for the furniture industry; decreasing returns are indicated.

Location Effects. First-order location parameters (α_{u1}, α_{u2}) are not significantly different from zero except for α_{u2} in the meat products model. Location in a small urban area is associated with lower real output in meat products manufacturing, independent of other inputs. For furniture, location affects the production function only through the second-order effects; that is, through its association with input productivity. Metropolitan location and location in small urban areas both are associated with higher productivity for labor and capital, relative to rural location, and lower productivity for materials. The secondary location effects in the meat industry are significantly positive with respect to labor in metropolitan areas and capital in small urban areas.

While interpretation of the coefficients associated with location is difficult when considered separately, an intuitive measure of the total location effect is the first derivative of the production function with respect to the qualitative variable:

$$TEFF_i = \alpha_{ui} + \alpha_{uil}(\overline{lnL}) + \alpha_{uim}(\overline{lnM}) + \alpha_{uik}(\overline{lnK}) \ , \quad i=1,2$$

where the subscript refers to either metropolitan or small urban location and the logs of the inputs are taken at the means for the sample. The overall effect of metropolitan and small urban location on production in both industries is shown in table 2. For meat products, establishments in metropolitan counties produce 5.2 percent more output, all else equal. The productivity of establishments in small urban counties is not significantly different from the productivity of their rural counterparts. For household furniture, metropolitan establishments are 6.6 percent more productive than rural establishments, but establishments in small urban locations have a greater productivity differential of 8.94 percent.

Fit

The data fit the translog production function model very well. The adjusted R^2 for each production function equation alone was 0.99 in the meat products model and 0.98 in the household furniture model. Because the production functions were estimated as part of a three-equation system, the fit of the system itself also was measured. The generalized R^2 for the three-equation system, which measures the proportion of the generalized variance explained by the right-hand variables in the system of equations, is defined as

$$R_s^2 = 1 - \frac{|E'E|}{|y'y|} \ ,$$

where y is the deviation of the dependent variable from its mean and E'E is the residual cross-products matrix (Berndt 1990). This statistic is reported in table 2. Normality tests of the residuals from each model led to failure to reject the null hypothesis of normality in each case.

Consistency Checks

Because the translog form does not satisfy global convexity properties, the estimated function must be tested for theoretical consistency. Outputs should increase monotonically with all inputs, and the isoquants should be convex. Monotonicity implies that the estimated marginal products of inputs are non-negative; convexity of isoquants requires that the principal minors of the bordered Hessian alternate in sign. Both monotonicity and convexity were found to hold at the means in both models. When checked at each data point, monotonicity was violated for 2.3 percent of the observations in household furniture, and for 6.2 percent of the observations in meat products. Convexity was violated for 11.3 percent of the data points for household furniture, and 34.5 percent of the data points for meat products.

Several options are available for correcting the model to improve theoretical consistency. One could apply the Lau (1978) technique for imposing convexity, but this usually destroys the flexibility of the translog function. A better alternative is to abandon the translog and reestimate the model using the generalized McFadden functional form developed by Diewert and Wales (1987). This function not only is flexible but also possesses a unique property: imposing the requisite theoretical restrictions will not destroy its flexibility. We defer these tasks to a future paper.

Elasticities

The structure of the estimated production function allows location to affect the production process both directly, through its effect on the intercept, and indirectly, through its effect on the elasticities. Table 3 shows output elasticities, price elasticities, and elasticities of substitution for rural, small urban, and metropolitan plants. The location parameters enter into the elasticity calculations through the formula for output elasticity:

$$\mu_i = \frac{\partial lnq}{\partial lnX_i} = \alpha_i + \sum_{i=1}^{3} \alpha_i * \overline{lnX_i} + \alpha_{u1i} * METRO + \alpha_{u2i} * SURB ,$$

where μ_i is the output elasticity of input i. For rural establishments, only the first two terms in the equation apply; for metropolitan establishments, α_{u1i} is added, and for small urban firms, α_{u2i} is added. The logs of the inputs are taken at the means for the entire industry.

Output Elasticities. The output elasticity of both labor and capital is higher in the furniture industry than in the meat products industry, reflecting the relatively low level of value added in the meat products industry. Within the meat products industry, the output elasticity of labor is highest in metropolitan areas, and the output elasticities of materials and capital are highest in small urban areas. In household furniture, output elasticity of labor and capital are both highest in small urban areas, but plants in rural areas exhibit the highest output elasticity of materials.

Price Elasticities. As required, all own-price elasticities are negative. Price elasticity of labor is higher in the meat products industry than in the household furniture industry. In both industries, the own-price elasticity of labor is most negative for rural establishments, although the differences in the household furniture industry are relatively small. This indicates that changes in wages within the furniture industry have less impact on rural industrial employment than changes in wages within the meat products industry.

Elasticities of Substitution. Morshima elasticities of substitution measure the percentage change in the ratio of factor demands for a percentage change in the price of one factor. Morshima elasticities are easily calculated from the price elasticities:

$$\sigma_{ij}^{M} = eij - ejj ,$$

where ϵ_{ij} is the price elasticity of demand for input i with respect to the price of input j. In table 3, the inputs are listed in the order i,j; the second input listed is the input whose price is allowed to change.

The Morshima elasticity estimates for both industries classify all inputs as substitutes. Ball and Chambers (1982) found similar elasticity results in their study for the meat products industry.

The lack of symmetry of the Morshima elasticities reveals the relative importance of the prices of different inputs in determining factor ratios. For example, a 10 percent change in the price of materials in the meat products industry in metropolitan areas will lead to about a 40 percent increase in the ratio of labor to materials. However, when the price of labor rises by 10 percent, the adjustment of the ratio of materials to labor is only about 33 percent. Hence, changes in the price of materials have a stronger impact on the input ratio. The same is true with respect to the ratio of capital to materials. Changes in the price of materials lead to stronger variations in the input ratio than do changes in the price of capital. Furthermore, the dominance of the effect of materials prices persists across locations.

In the household furniture industry, the price of materials is much less important to the structure of the technology. The elasticities of substitution between materials and other inputs are almost symmetric, and the dominance of materials reverses in rural areas in the case of the labor/materials ratio.

<u>Relative Multifactor Productivity</u>

Multifactor productivity is usually defined as the ratio of output to an index of inputs. However, a relative measure of productivity for each establishment is the value of that establishment's residual from the estimated output equation. This indicator has been used by Lichtenberg and Siegel in their analysis of changes in productivity due to ownership changes (1987).

In order to focus on the relationship between location and relative multifactor productivity, the translog model was estimated without location variables for each industry. The residuals from the output equation were averaged across firms by urban class; the averages are displayed in table 3, with T ratios in parentheses.

In the meat products model, the average of the residuals across metropolitan establishments was significantly positive, indicating a level of productivity 2.4 percent higher in the average plant. The average across rural establishments was significantly negative, indicating that rural plants were about 3 percent less productive than the average. For the furniture industry, rural establishments were about 5 percent less productive than the average; other location groups showed no significant deviations from the average productivity.

Observations

The results of estimating the three-factor translog production function systems for meat products and household furniture show that general differences can be found in technology and productivity among plants in the same industry but in different location classes. Firms located in metropolitan areas were more productive than their rural counterparts in both industries; firms located in small urban areas were most productive in the household furniture industry. These results were confirmed by both the total location effect and the relative multifactor productivity measures.

Variations in the technology of plants in different industries and locations led to variations in the output and price elasticities and in the elasticities of substitution. The demand for labor is most elastic in the meat products industry; in both industries, rural labor demand is most elastic. All inputs are substitutes for each other, but their substitutability varies across location. Materials costs are an important influence on technology in meat products. As the price of materials rises, labor and capital are applied more intensively in order to derive more output from a given level of raw materials. The price of materials has a weaker influence on the input vector in household furniture.

5. Location, Size, and Other Effects

Estimation results regarding the relative productivity of metropolitan, small urban, and rural areas must be interpreted with caution. Although they seem to suggest that a meat products manufacturer would be most productive in a metropolitan area, whereas a furniture manufacturer would be most productive in a small urban location, there are a number of factors that remain unaccounted. In fact, the lack of consistency of the findings across industries suggests that industry- and plant-specific variables may be important in determining the effect of location on the productivity of manufacturing.

Size Effects

Some clues regarding industry differences appear in table 1. The most obvious difference is the size of the average plant; meat products manufacturers are typically much larger than furniture manufacturers. On the average, the small urban areas have the largest establishments, and the rural areas have the smallest. Establishment size may play a role in determining the most productive location.

To investigate the effects of size, each industry was separated into three size classes. The divisions were chosen so that roughly 50 percent of the plants fell into the smallest size class, and 25 percent fell into each of the larger size classes. Two procedures were followed to investigate the effects of size: one using the original three-factor translog production function, and the other estimating models separately for each size class.

First, average multifactor productivity was calculated for each size class in each industry, independent of the location variable. The results are reported in table 4. In the meat products industry, the middle-size class was 6 percent more productive than average, while the smallest plants were 3 percent less productive. The smallest plants are more heavily distributed in rural areas than plants in the other two size classes. In household furniture, the largest quartile of firms was about 5 percent more productive than the average. These plants are more heavily represented in small urban areas than the other two size classes.

The observations above suggest that plants of different size classes may experience location impacts to differing degrees. In order to investigate this possibility, the full translog production function system was estimated separately for each size class. Hypothesis tests for location effects were performed; the total location effect was calculated; and the multifactor productivity measures were obtained relative to each size class in each industry. The results are summarized in table 5.

The results obtained from the original model regarding productivity and location remained valid only for one size class in each industry. In meat products, location continued to be associated with productivity only for the smallest firms. This is confirmed by the significance of the total location effect for metropolitan plants, and by the relative multifactor productivity measures. In household furniture, location effects disappeared for the smallest two size classes; however, the results reported for the original estimation regarding location and productivity were still valid for the largest size class.

Timing of Entry and Survival

Another factor possibly affecting the observed productivity differences between rural and urban establishments is the timing of the entry of the establishment into the industry. The capital stock of new entrants is likely to embody newly available production technology, which should contribute to the productivity of these plants relative to existing establishments. However, the existence of internal adjustment costs, which has been verified by Lichtenberg (1988), may dampen the capital embodiment effect over a period of one or more years from the time of initial investment in plant and equipment (McHugh and Lane, 1990).

Table 6 shows the distribution of entrants and survivors by year and location. An establishment is identified as an entrant if it is not observed in the industry in a previous census year

(1972 or 1977). In 1977 and 1982, in both the meat products and household furniture industries, new entrants represented a greater percentage of the total number of plants in rural counties than in either metropolitan or small urban counties.

The rate of survival of entering plants varies across location and size. In both industries, the survival of 1977 entrants to 1982 is highest in metropolitan areas. In meat products, survival is lowest in small urban areas, and in household furniture, it is lowest in rural areas. When survival rates were averaged over establishments in the size classes defined in the previous section, the average survival rate for large 1977 entrants in the meat products industry was 65.9 percent, whereas small plants had a survival rate of only 25.7 percent. Large meat products plants were most likely to survive when they located in rural areas. In household furniture, the difference in the survival rates of small and large plants was less pronounced; small plants had a survival rate of 25.5 percent, while large plants had a survival rate of 48.6 percent. Large plants were equally likely to survive in metropolitan and small urban areas.

Table 7 shows average relative multifactor productivity for existing plants, 1977 entrants, and 1982 entrants. In both industries, lower levels of relative productivity were observed for firms entering in 1977 than for existing firms. However, by 1982, the performance of surviving 1977 entrants did not significantly differ from the performance of plants already active in 1972. This change in the relative productivity of entering plants suggests that new plants do experience an initial period of low productivity, and that the timing of entrance, relative to the sample period, may affect overall productivity for the group.

Plants entering in 1982 have significantly lower productivity in 1982 than other plants. However, because our data do not extend beyond 1982, we cannot observe whether these plants recover from their initial low productivity period, as was observed for the 1977 entrants. Since 1982 entrants are a relatively large percentage of the plants observed in rural areas, the timing of the entry of these plants at the end of the sample period may skew our rural productivity measures downward. The relatively low productivity in rural areas that we have attributed to location may actually be the effect of a large percentage of new entrants in rural areas.

These observations suggest possibilities for analysis of changes in the impact of location on productivity over time. By estimating production functions separately for groups of plants entering in different census years, the impact of location on a new plant's productivity and survival could be examined over time, controlling for the age of the plant. Possible connections between new plant survival and rural development and entrepreneurship initiatives could be explored.

Other Effects

Size and timing of entry have been examined as examples of industry- or firm-specific variables that may affect productivity in different locations. However, there are a number of factors that vary across industries and that may contribute to the impact of location on the productivity of firms. For example, Nguyen and Reznek (1991) found that small, single-unit wood furniture manufacturing plants were more productive than their counterparts that were part of a multi-unit firm. Other establishment-specific variables that might influence productivity by location include unionization of the labor force, the skill structure of the plant's labor force, the age of the plant and equipment, and research and development.

Location-specific variables should be considered as well. Not all metropolitan locations have the same characteristics with respect to available labor markets, distance of output markets, proximity of suppliers, transportation services, or other infrastructure such as water, sewerage, and power. Rural areas also vary dramatically with respect to these location-specific variables. Exploration of these influences may provide guidelines of the resources necessary for manufacturers to remain productive in rural areas.

6. Conclusions

Translog production function systems were estimated to investigate selected aspects of the effect of rural, small urban, and metropolitan locations on productivity in the meat products and household furniture sectors. Statistically significant location effects were found for both industries. The estimated models fit the data very well and standard diagnostics for convexity and monotonicity showed only minor theoretical problems.

In the meat products industry, metropolitan location was associated with higher productivity. However, this result held only for relatively small meat products manufacturers; plants in larger size classes showed no significant location effect for productivity. Household furniture plants in small urban locations had the highest productivity, and plants in metropolitan locations were more productive than their rural counterparts. However, these location effects were significant only for the largest class of household furniture manufacturers.

While this analysis is specific to two industries, it suggests that development policies targeting manufacturing can be made more effective by focusing on industries and plants with characteristics that predispose them to the locations being supported. For example, the larger meat products manufacturers showed no significant productivity differences between locations. Incentives required to attract these plants to rural locations should be small or minimal. However, relocating a large household furniture manufacturer from a small urban location to a rural location might require larger subsidies, either directly or through publicly funded improvements in industry-specific resources such as work force training and infrastructure development.

Other industry- and firm-specific characteristics that may affect productivity in rural and urban areas include requirements for work force education, dependence on natural resources, linkages to other industries, and reliance on a particular consumer market. Better understanding of the tradeoffs between productivity and location for plants and industries with different characteristics may assist development policymakers in focusing on industries and types of plants most likely to be productive and competitive, contributing to the long-run economic base. This brief assessment of entry and productivity suggests, however, that the full benefits of location may require time to be fully reflected in productivity. Alternatively, these results suggest that dynamic analysis can yield information on phasing of location incentives.

Table 1
Characteristics of the Meat Products and Household Furniture Industries:
Size and Productivity

Industry/ Location	SampleSize	Value of Output[a]		Employment		Productivity Indicators		
		Average	% Above avg.[b]	Average	% Above Avg.[b]	% Value Added[c]	Output/ Lab. Hr[d]	Capital/ Lab. Hr[d]
Meat Products	2,187	31,158	18.7	126.3	21.2	16.0	82.3	8.7
Metropolitan (0-3)	1,056	29,672	19.8	131.4	20.3	16.7	85.7	9.2
Small Urban (4-5)	245	49,100	15.9	182.8	23.7	16.0	74.0	7.6
Rural (6-9)	886	27,969	18.4	104.6	23.1	15.1	80.7	8.3
Household Furniture	1,202	3,146	22.5	53.2	25.1	33.1	28.5	5.6
Metropolitan (0-3)	841	3,097	23.4	51.7	24.4	33.1	29.6	5.8
Small Urban (4-5)	94	4,797	23.4	80.1	22.3	33.6	31.3	5.8
Rural (6-9)	267	2,722	21.4	48.7	25.1	33.2	23.9	5.2

a. Total value of shipments, adjusted for changes in inventory, thousands.

b. Percentage of observations lying above the mean.

c. Value added as a percentage of total output.

d. Real value of output (deflated) per production worker hour.

e. Value of the capital stock per production worker hour.

Table 2
Parameter Estimates of the Translog Production Function
for the Meat Products and Household Furniture Industries

	Meat Products		Household Furniture	
	Estimate	T Ratio	Estimate	T Ratio
First-Order Effects				
α_o	1.41*	(63.16)	1.95*	(58.34)
α_l	0.42*	(77.65)	0.58*	(76.16)
α_m	0.48*	(67.51)	0.36*	(57.02)
α_k	0.11*	(10.33)	0.05*	(100.66)
Second-Order Effects				
α_{ll}	0.08*	(45.52)	0.16*	(44.59)
α_{mm}	0.12*	(47.69)	0.17*	(53.69)
α_{kk}	0.02*	(268.45)	-0.03*	(-5.41)
α_{lm}	-0.09*	(-55.57)	-0.15*	(-52.96)
α_{kl}	0.01*	(3.96)	-0.01*	(-4.22)
α_{km}	-0.03*	(12.41)	-0.02*	(-3.82)
Scale (λ)	1.00	(-0.84)	0.98*	(-3.25)
Location Effects				
α_{u1}	-0.02	(-0.77)	-0.05	(-1.30)
α_{u2}	-0.18*	(-4.28)	-0.09	(-1.07)
α_{u1l}	0.01*	(4.33)	0.02*	(3.46)
α_{u1m}	-0.01	(-1.19)	-0.02*	(-3.91)
α_{u1k}	0.03	(1.84)	0.03*	(3.68)
α_{u2l}	0.01	(0.63)	0.02*	(2.21)
α_{u2m}	0.01	(1.30)	-0.03*	(-3.25)
α_{u2k}	0.03*	(2.83)	0.05*	(3.33)
Total Location Effect				
Metropolitan	5.20*	(5.23)	6.60*	(2.58)
Small Urban	2.47	(1.47)	8.94*	(2.06)
R^2 (System)	.994		.997	

Note: For λ, the T ratio refers to the hypothesis that it is not equal to 1.

* Indicates a parameter is significantly different from 0 at α = .05.

Table 3
Elasticities and Multifactor Productivity
for the Meat Products and Household Furniture Industry

	Meat Products			Household Furniture		
	Metro	Small Urban	Rural	Metro	Small Urban	Rural
Output Elasticities						
Labor	0.15	0.14	0.13	0.34	0.34	0.32
	(5.41)	(3.27)	(55.68)	(15.04)	(15.76)	(4.67)
Materials	0.82	0.84	0.83	0.59	0.58	0.61
	(27.56)	(19.06)	(64.41)	(15.15)	(25.50)	(106.96)
Capital	0.05	0.06	0.04	0.08	0.10	0.05
	(1.41)	(1.91)	(1.17)	(3.31)	(3.64)	(2.06)
Price Elasticities						
Labor	-2.70	-3.31	-4.17	-2.40	-2.42	-2.67
	(-112.03)	(-49.76)	(-87.06)	(-93.57)	(-49.44)	(-158.44)
Materials	-0.79	-0.78	-1.13	-1.50	-1.57	-1.44
	(-148.31)	(-85.06)	(-61.31)	(-102.44)	(-57.35)	(-127.29)
Capital	-0.94	-0.56	-2.06	-0.97	-0.68	-3.05
	(-3.62)	(-4.87)	(-8.59)	(-4.68)	(-1.30)	(-47.35)
Elasticities of Substitution (Morshima)						
Labor, Materials	4.05	4.33	6.06	3.80	3.92	3.81
	(150.51)	(80.17)	(77.62)	(110.46)	(120.35)	(141.34)
Materials, Labor	3.25	3.91	5.01	3.73	3.78	4.03
	(119.56)	(52.63)	(88.88)	(101.24)	(201.38)	(158.46)
Labor, Capital	0.78	0.45	1.55	1.03	0.74	3.16
	(18.69)	(30.97)	(2.08)	(128.26)	(151.49)	(74.53)
Capital, Labor	1.49	2.46	0.48	2.86	2.85	3.48
	(3.09)	(4.04)	(6.93)	(4.94)	(288.17)	(47.53)
Capital, Materials	4.41	3.39	8.61	2.70	2.61	3.72
	(14.62)	(25.40)	(19.81)	(23.44)	(7.81)	(56.72)
Materials, Capital	1.03	0.62	2.23	1.06	0.76	3.23
	(3.83)	(5.25)	(8.99)	(4.90)	(29.07)	(47.85)
Productivity	0.02	-0.00	-0.03	0.01	0.05	-0.05
	(3.42)	(-0.18)	(-2.48)	(1.43)	(1.84)	(-2.95)

Notes: Some figures appear as zeros as a result of rounding

T ratios are in parentheses.

T ratios for price elasticities and elasticities of subsitutution are calculated from standard errors generated by 100 iterations of Efron's bootstrap procedure (Efron 1979).

Table 4

Multifactor Productivity by Size and
Distribution of Establishments by Size and Location

	Meat Products			Household Furniture		
Size (No. of Employees)	0 - 20	21 - 100	> 100	0 - 15	16 - 50	> 50
Relative MFP	-0.03*	0.06*	0.00	0.00	-0.01	0.05*
	(-3.97)	(3.86)	(0.49)	(0.36)	(-1.45)	(3.37)
Observations	1103	532	552	616	275	310
Percent						
Metropolitan	43.1	58.8	48.5	72.0	68.8	66.8
Small Urban	11.8	8.1	13.0	4.9	9.4	12.3
Rural	45.1	33.1	38.4	23.1	21.7	21.0

Notes: T ratios are in parentheses.

* indicates statistical significance at α = .05.

Table 5
Estimation Results
Separate Translog Production Functions for Each Size Class

	Meat Products			Household Furniture		
Size (No. of Employees)	0 - 20	21 - 100	> 100	0 - 15	16 - 50	> 50
	(N = 1103)	(N = 532)	(N = 552)	(N = 616)	(N = 276)	(N = 310)
Hypothesis Tests						
No Metro Effects	T^{o} = 64 Reject	T^{o} = 44 Reject	T^{o} = 58 Reject	T^{o} = 36 Reject	T^{o} = 12 Reject	T^{o} = 21 Reject
No Small Urban Effects	T^{o} = 18 Reject	T^{o} = 4 Accept	T^{o} = 39 Reject	T^{o} = 11 Reject	T^{o} = 4 Accept	T^{o} = 14 Reject
Returns to Scale (λ)	1.01^{C} (0.82)	0.85^{D} (-55.89)	0.92^{D} (-9.76)	$.96^{D}$ (-2.85)	$.97^{C}$ (1.16)	0.95^{D} (2.27)
Total Effect						
Metropolitan	0.06* (4.62)	-0.03 (-1.24)	0.02 (0.45)	0.07 (1.43)	.03 (0.71)	0.08* (2.51)
Small Urban	0.00 (0.14)	-0.06 (-1.14)	0.0 (1.01)	0.09 (.793)	0.03 (0.40)	0.10* (2.04)
Multifactor Productivity						
Metropolitan	0.03* (3.57)	-0.01 (-0.64)	0.00 (0.03)	0.01 (1.19)	0.01 (0.25)	0.01 (0.73)
Small Urban	-0.03 (-1.77)	-0.03 (-0.57)	0.06* (2.15)	0.05 (1.12)	0.02 (0.28)	0.04 (0.92)
Rural	-0.02* (-2.25)	0.02 (0.59)	-0.02 (-1.46)	-0.05* (2.30)	-0.02 (-0.55)	-0.07* (-2.05)

Notes: I, C, D indicate λ is significantly greater than, equal to, or less than 1 - increasing, constant, or decreasing returns to scale.

T ratios are in parentheses; for λ, T ratio refers to a two sided hypothesis test that $\lambda = 1$.

Some numbers appear as zeros as a result of rounding.

* indicates statistical significance at $\alpha = .05$.

Table 6
Characteristics of the Meat Products and Household Furniture Industries: Entrants and Location

	1977			1982			Surviving 1977 Entrants[a]	
	Total Plants	Entrants	Pct. Entrants	Total Plants	Entrants	Pct Entrants	No.	Pct. Entrants
Meat Products	808	341	42.2	597	224	16.6	117	34.3
Metropolitan	376	145	38.6	283	102	15.9	54	37.2
Small Urban	89	31	34.8	63	22	14.9	9	29.0
Rural	343	165	48.1	251	100	18.0	54	32.7
Household Furniture	434	239	51.5	317	135	17.0	73	30.5
Metropolitan	312	154	49.4	219	90	16.3	53	34.4
Small Urban	41	21	51.2	26	6	10.7	6	28.6
Rural	111	64	57.7	72	39	20.7	14	21.9

a. 1977 entrants still operating in 1982.

Table 7
Relative Multifactor Productivity
Existing Plants versus New Entrants

	Average MFP[a]	1972 MFP	1977 MFP	1982 MFP
Meat Products				
Existing Plants	0.01 (1.79)	-0.00 (-0.21)	0.03* (2.69)	0.02 (1.63)
1977 Entrants	0.01 (0.50)	--	0.02 (1.62)	-0.04 (-1.69)
1982 Entrants	-0.09 (-6.13)	--	--	-0.09 (-6.13)
Household Furniture				
Existing Plants	0.00 (0.31)	-0.04* (-2.71)	0.05* (4.05)	0.03 (1.29)
1977 Entrants	0.04* (2.59)	--	0.03* (2.15)	0.04 (1.44)
1982 Entrants	-0.07* (-2.53)	--	--	-0.07* (-2.53)

Notes: a. Averaged over each year of operation.

T ratios are in parentheses.

* Indicates the average is statistically different from zero at significance level .05.

References

Ball, V. E., and R. G. Chambers. "An Economic Analysis of Technology in the Meat Products Industry." Amer. J. of Agr. Econ. 64(1982): 699-709.

Berndt, E. R. The Practice of Econometrics: Classic and Contemporary. Reading, Mass.: Addison-Wesley, 1990.

Butler, M. A. Rural-Urban Continuum Codes for Metropolitan and Nonmetropolitan Counties (AGES 90-28). Washington, D.C.: United States Department of Agriculture, Economic Research Service, 1990.

Diewert, W. E., and J. T. Wales. "Flexible Functional Forms and Global Curvature Conditions." Econometrica 55(1987):43-68.

Doms, M. Capital Measurement and Vintage Effects. Center for Economic Studies, Discussion Paper. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census, 1991.

Efron, B. "Bootstrap Methods: Another Look at the Jackknife." Ann. Statist. 7(1979):1-26.

Gallant, A. R., and D. W. Jorgenson. "Statistical Inference for a System of Simultaneous, Nonlinear, Implicit Equations in the Context of Instrumental Variables Estimation." J. Econometrics 5(1979):71-88.

Guilkey, D. K., C. A. K. Lovell, and R. C. Sickles. "A Comparison of the Performance of Three Flexible Functional Forms." Int. Econ Rev. 24(1983):591-616.

Lau, L. J. "Testing and Imposing Monotonicity, convexity, and Quasi-Convexity Constraints." Production Economics: A Dual Approach to Theory and Application, Vol I, ed. M. Fuss and D. McFadden. Amsterdam: Elsevier/North Holland, 1978.

Lichtenberg, F. R. "Estimation of the Internal Adjustment costs Model using Longitudinal Establishment Data." Rev Econ. Statist., 70(1988):421-430.

Lichtenberg, F. R. and D. Siegel. "Productivity and Changes in Ownership of Manufacturing Plants." Brookings Pap. Econ. Act. 3(1987):643-81.

McGuckin, R., and G. Pascoe. "The Longitudinal Research Database: Status and Research Possibilities." Surv. Curr. Bus. November(1988):30-37.

McHugh, R., and J. Lane. "Embodied Technical Change and Tests of the Internal Adjustment Cost Hypothesis." J. Bus. Econ. Statist. 8(1990):459-464.

Nguyen, S. V., and A. P. Reznek. "Returns to Scale in Small and Large U.S. Manufacturing Establishments." Small Bus. Econ. **3(1991):197-214.**

Otto, D., S. R. Johnson, H. Jensen, and S. A. Martin. "Rural Economic Development Policies for the Midwestern States." Rural Poverty: Special Causes and Policy Reforms, ed. H. Rodgers, Jr. and G. Weiher. New York: Greenwood Press, 1989.

Usher, D. The Measurement of Capital. Chicago: University of Chicago Press, 1980.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." J. Amer. Stat. Assoc 58(1962):977-92.