Modeling Scale Economies in Supermarket Operations:
Incorporating the Impacts of Store Characteristics and Information Technologies

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Abstract: Information and internet-based technologies have fostered new supply chain initiatives in food retailing but little research has evaluated productivity impacts. A ray-homothetic production function is estimated for supermarkets to investigate the productivity effects of key variables such as format, competitive position, self-distributing chain membership, unionization, and information technologies adoption.

Key words: ray-homothetic production function, food retail productivity, supply chain initiatives

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New information and communications technologies are having profound impacts on business operations, decision processes, and trading partner relationships in all sectors of the global economy. The food retailing sector is no exception. During the 1970s and 1980s the development and widespread adoption of scanning technology and the Uniform Product Code provided the technological foundation for the introduction of electronic transmission of order data, industry-supported mechanisms for sharing scanner data, and computer-based product movement analysis at the store level. At the same time, information technology was the basis for significant changes in warehouse operations, logistics systems, and manufacturing processes. (Walsh, pp. 89-106; King and Phumpiu). In the 1990s the Efficient Consumer Response initiative brought together food retailers, wholesalers, brokers, and manufacturers in an industry-wide collaborative effort to foster adoption of new technologies and business practices based on information technology (Kurt Salmon Associates, Inc.). More recently, rapid development of Internet-based technologies has fostered new initiatives in electronic commerce; scan-based trading; and collaborative planning, forecasting, and replenishment (Kinsey).

While the impacts of information technology on business operations and industry structure in the food retailing sector have been described and discussed by many, relatively little is known about how these changes have affected productivity at the store level. This paper addresses this gap in our knowledge by presenting results of a production function analysis of supermarket operations. Data for this study are from the 2001 Supermarket Panel conducted by the Food Industry Center at the University of Minnesota (King, Jacobson, and Seltzer). The Supermarket Panel is an annual survey of supermarkets. Store managers provide information on

store characteristics, operations, and performance. The 2001 Panel consists of 563 stores

selected at random from the nearly 32,000 supermarkets in the U.S.

This analysis builds on recent work by Bresnahan, Brynjolfsson, and Hitt incorporating

workplace organizational trends and clusters of new information technologies into the

specification and estimation of firm level production functions. A ray-homothetic specification

proposed by Färe, Jansson, and Lovell (FJL) is used in this study to estimate a store-level

production function with weekly sales minus cost of goods sold as the output measure and two

inputs, labor (hours per week) and store selling area (square feet). This specification allows for

considerable flexibility in estimating returns to scale and ideal output and does not require data

on input prices, which are not available for this data set. Binary variables are added to the model

to investigate the productivity effects of store location, format, competitive position, membership

in a self-distributing chain, unionization, and the adoption of a variety of new information

technologies.

In the sections that follow, we first develop a theoretical framework for analysis of

supermarket production technology. We then briefly describe data collection procedures and

sample characteristics for the 2001 Supermarket Panel and specify the empirical model for our

analysis. In the remainder of the paper, we present the results of our statistical analysis and

conclude with a discussion of the implications of our findings and directions for future research.

Production Technology of Food Retailing Firms

Productivity analysis of retail trades such as the supermarket industry adapts standard

production theory relating inputs to outputs by including the role of distribution, which turns

consumers into customers. A general statement of the economic objective of the food retail distribution sector is to provide goods and services along with a set of distribution services for the customer. In general retail analysts have classified distribution services into five broad categories: (1) accessibility of location, (2) breadth and depth of location, (3) assurance of timely and quality-assured product delivery, (4) information, and (5) ambience (Anderson and Betancourt). Providing higher levels of distribution services results in higher costs for food retailers, as the distribution services are viewed as an output in the production function framework. The analysis of supermarket operations presented here accounts for these measures by incorporating store characteristics, competitive environment, business organization, and technology adoption at the store level.

Analytical work on productivity in retailing has suggested that there are substantial economies of scale in the economic organization of retailing. Oi discusses how the economies of massed reserves is applied to the retail firm: a doubling of both the customer-arrival rate and the number of checkout clerks leads the number of transactions to more than double. Therefore, retail firms can achieve larger sizes with lower unit operating costs. Oi's supplements his analytical approach with simple linear empirical models showing a positive relationship between store size and transaction size, confirming the impact of increasing returns for food stores. More recently, Anderson and Betancourt note that if costs are more responsive to increases in the number of transactions than to the size of transactions, then economies of scale are present as store size rises.

Production theory provides flexible functional forms which can provide more insight into the nature of returns to scale. The class of ray-homothetic production functions developed by

FJL allows returns to scale to vary both with output and input mix. Ideal output, where average variable cost achieves its minimum, also depends on the firm's input mix. The ray-homothetic production function is flexible in encompassing other more restrictive but often specified forms – such as ray-homogeneity, homotheticity, and homogeneity – with testable parametric restrictions. Recent work in production theory has reconfirmed that value of considering ray-homothetic technologies. Chambers and Mitchell show that input homothetic and homogeneous multi-output technologies are both special cases of ray-homothetic technologies, whose defining characteristic is a linear expansion path that passes through the origin. Färe and Mitchell demonstrate that the existence of output scaling laws and separable cost functions are defined if and only if the underlying technology is ray-homothetic.

The structure of the food retailing production function used in this study is represented by the production function φ where the firms produces output V using inputs x, which are scaled by $\lambda \geq 1$. A ray-homothetic production function satisfies the functional equation

$$\varphi(\lambda \cdot x) = F\left[\lambda^{H(x/|x|)} \cdot F^{-1}(\varphi(x))\right], \quad where \ \lambda > 0, \quad |x| = \left[\sum_{i=1}^{n} x_i^2\right]^{1/2} \tag{1}$$

where F and H meet a set of well-defined properties. FJL establish the complete properties of these functions, which basically require that F be bounded, strictly increasing, and continuous and that H is positive and bounded. The term $|x|$ represents the Euclidean norm of x.

Restrictions on the form of H and F generate specific forms of the production function including ray-homogeneity, homotheticity, and homogeneity. For example, a homogeneous

production function such as the Cobb-Douglas form, is implied if F is the identity function and H(x/|x|) is a positive constant α so that

$$\varphi(\lambda \cdot x) = \lambda^{\alpha} \cdot \varphi(x) \tag{2}$$

The production functions nested within the general form also imply relationships for the scale economies measure ε which is defined as

$$\varepsilon \equiv \lim_{\lambda \to 1} \left(\frac{\partial \varphi(\lambda \cdot x)}{\partial \lambda} \frac{\lambda}{\varphi(x)} \right) . \tag{3}$$

For the ray-homothetic function the scale elasticity is $\varepsilon_{rh} = \varepsilon_1(x / |x|, \varphi(x))$, while for homogeneous functions the scale elasticity $\varepsilon_h = \alpha$, which is a constant. Ideal output for the ray-homothetic function will depend on the input mix and is obtained by setting $\varepsilon_{rh} = 1$ and solving for output.

Estimation of the general form of the ray-homothetic production function requires specific functional forms for the core function $\varphi(x)$, for the output scaling function F(V), and for the input mix scaling function H(x/|x|). For the empirical work on the supermarket industry the core function is based on a Cobb-Douglas model, while the Zellner-Revankar specification is used for the size of output scaling F(V). The input mix scaling function uses a modified Cobb-Douglas framework. FJL show that with these choices the two input case of the ray-homothetic production function is

$$V e^{\theta V} = A x_1^{\alpha + \gamma \sin Z} x_2^{\beta + \gamma \sin Z} . \tag{4}$$

Introduction of a multiplicative error term in equation (4) facilitates the transformation of the

model into a loglinear specification for estimation:

$$\ln V + \theta V = \ln A + \beta_1 X_1 + \beta_2 X_2 + \gamma \sin Z \left[\ln X_1 + \ln X_2 \right] + u_i \tag{5}$$

where the sin Z represents the angle formed by the X_1 / X_2 ratio. Estimation proceeds by

maximum likelihood, assuming that the error term is an independently and identically distributed

normal random variable with the full log likelihood function presented in FJL.

The value of the ray-homothetic specification is the flexibility in modeling input

elasticities and measures of scale economies. Scale economies for this form can vary with the

rate of output and the input mix, and the response of ideal output to the mix of inputs used by

food retailers can be identified. Applying the definition of the returns to scale measure ε to the

ray-homogeneous production function in (5) gives:

$$\varepsilon_{rh} \left[\frac{x}{|x|}, \varphi(x) \right] = \frac{\alpha + \beta}{1 + \theta V} + \frac{2\gamma \sin Z}{1 + \theta V} \quad . \tag{6}$$

For a food retailer producing at the ideal output level $\varepsilon_{rh} = 1$ and this implies the level of output

$$V_1^0 = \frac{\alpha + \beta - 1}{\theta} + \frac{2\gamma \sin Z}{\theta} \tag{7}$$

which shows that ideal output depends on the input mix.

Data Collection and Sample Characteristics

The Supermarket Panel is an annual, nation-wide survey of supermarkets that collects

data on store characteristics, operating practices, and performance. The Panel was established in

1998 by the Food Industry Center at the University of Minnesota as a basis for ongoing study of the supermarket industry. Panel data booklets are mailed directly to store managers each January. Each respondent receives a customized benchmark report comparing his/her store to a peer group of stores similar in size and format. This is the only incentive store managers receive for participation. The Panel is unique because the unit of analysis is the individual store, and stores are tracked over time. In contrast, findings presented in the *Annual Report of the Grocery Industry* published by *Progressive Grocer* and the Food Marketing Institute's annual *SPEAKS* report are based on company-level responses for representative stores.

Data collection procedures for the 2001 Supermarket panel are described in detail by King, Jacobson, and Seltzer. The population for the 2001 Supermarket Panel was defined as the 31,356 establishments classified as supermarkets on a USDA list of the 158,168 establishments in the United States that accept food stamps. The sample for 2001 included 368 stores that had previously participated in the Panel and an additional 1,632 stores drawn at random from the remaining 30,970 stores in the population, yielding a total sample of 2000 stores. Prior to the initiation of data collection, the Food Industry Center and IGA agreed to send the 2001 Panel to all of the IGA stores in the United States. This increased the total sample size for the 2001 Panel to 3,601 stores. Of these, 563 stores returned useable data booklets, an overall response rate of 15.6%.

King, Jacobson, and Seltzer (pp. 4-5) note that median characteristics for all stores in the 2001 Panel are similar to figures presented in the *68th Annual Report of the Grocery Industry* published by *Progressive Grocer* in April 2001. They also provide extensive descriptive information for stores in the 2001 Supermarket Panel grouped by format, ownership group size,

relative scores for each of six management practice indices, and ownership relationship to the store's primary distribution center. Differences in stores grouped by relationship to the primary distribution center – wholesaler supplied or member or a self distributing group – are especially striking and important in light of structural changes in the industry that point to greater consolidation and more vertical coordination. These are presented in Table 1. It is noteworthy that wholesaler supplied stores are located in less densely populated areas with lower median household income, are smaller and have lower weekly sales, and are less likely to adopt more progressive management practices, including supply chain practices made possible by new information technologies. Differences are less clear-cut with respect to store performance. Wholesaler supplied stores have lower sales per square foot, sales per labor hour, and sales per transaction and higher payroll as a percent of sales. However, median inventory turns, labor turnover, gross margins, and sales growth for wholesaler supplied stores compare favorably median performance for stores that are part of a self distributing chain. Particular attention in this study is focused on the question of whether these differences are indicative of a fundamental difference in production technology for these two groups of stores.

Empirical Model

The output measure used in this analysis weekly value-added, defined as weekly sales minus the cost of goods sold.[1] Baily and Solow (p. 159) provide support for this, stating that the "value-added generated by retailers provides the best simple measure of retailing output." They

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[1] In this study weekly value-added was calculated by multiplying average weekly sales by gross margin as a percentage of sales.

go on to note that measured output from the retailing sector should reflect the amount of retail service that is provided. Service dimensions for food retailing can include the variety of merchandise provided, convenience of store location, characteristics of the store neighborhood, availability of checkout and food department personnel, along with the accessibility of special in-store services such as salad bars, home meal preparation, pharmacy counters, photo development and other services.

Two critical inputs are considered in this analysis: (1) store selling area, and (2) weekly labor hours. Store selling area is a good, though not perfect, measure of the capital used in a retail operation. Other major capital inputs, such a refrigeration equipment and lighting, shelving and display cases, and front-end checkout equipment are highly correlated with store selling area. The second input, weekly labor hours, is the sum of full-time and part-time labor hours. Preliminary analysis showed that full-time and part-time labor hours can be aggregated without loss of explanatory power.

In-store investments in information technology and adoption of business practices based on new information technologies are also expected to affect productivity. In their analysis of supply chain technologies, King, Jacobson, and Seltzer (pp. 12-22) group a set of ten technologies/practices into three general categories:

- EDI and Internet-based data sharing technologies (electronic transmission of orders, electronic receipt of invoices, electronic transmission of movement data, and Internet/Intranet links to key suppliers),

- technologies that facilitate decision sharing (scan-based trading and use of scanner data for automatic inventory refill), and

- technologies that support product assortment, pricing, and merchandising decisions (product movement analysis/category management, plan-o-grams for shelf space allocation, electronic shelf tags, and frequent shopper/loyalty card programs).

Binary variables for five key technologies from this larger list are included in this analysis: (1)

electronic receipt of invoices, (2) scan-based trading, (3) use of scanner data for automatic

inventory refill, (4) plan-o-grams for shelf space allocation, and (5) frequent shopper/loyalty card

programs. Recognizing that technology adoption decisions are likely to be influenced by output

level and therefore endogenous, the binary variable for each technology was set equal to one only

if the store reported adoption of the technology one or more years prior to the survey. Therefore,

the technology adoption variables are predetermined in the model.

Though not actual inputs, two important organizational characteristics may also have a

significant impact on store productivity. The first is the nature of the business relationship with

the store's primary distribution center. Stores and distribution centers are under common

ownership for self-distributing chains. This facilitates coordination between these two segments

of the retail supply chain and so may yield productivity gains. Also, the number of stores under

common ownership is generally larger for self-distributing chains, and stores in larger groups

may benefit from size economies in management training and procurement. To capture these

effects, the empirical model includes a binary variable equal to zero if the store is wholesaler

supplied and one if the store is part of a self-distributing group. Unionization is a second

organizational factor that may affect productivity if having a unionized workforce is associated

with significant differences in worker skills and/or workforce stability. A binary variable equal

to one if at least 25% of the workforce is covered by a collective bargaining agreement and zero

otherwise is also included in the empirical model.

Market characteristics are also expected to affect supermarket productivity. For example,

location is often cited as a key determinant of sales volume and store performance. Two

variables often associated with the attractiveness of a retail market are included in this analysis:

(1) population density and (2) median household income. Both measures are based on census

data for the zip code in which a store is located. Population density is an indicator of the

potential number of customers near the store. Median household income is an indicator of

affluence, which affect not only the volume of food purchases but also the product mix, with

higher income shoppers expected to purchase higher valued food products.[2]

Finally, value-added can vary significantly across store formats. For example, Baily and

Zitzewitz document a case where a specialty retailing chain achieved value-added per dollar of

sales that was 2.3 times higher than that of a mass-market discounter. Stores in the 2001

Supermarket Panel are grouped into four mutually exclusive, exhaustive format categories: (1)

conventional, (2) upscale, (3) food/drug combination, and (4) warehouse. King, Jacobson, and

Seltzer report considerable variation in median store characteristics and performance measures

for stores grouped by format. The critical question, though, is whether these format effects can

be accounted for by systematic differences in input levels and other productivity shifters across

formats. In order to explore this question, binary variables for these format categories are

included in empirical model for this study.

In specifying the functional form for the empirical model, information technology,

organization, market, competitive position, and format variables are all introduced as scale

shifters. The loglinear specification of the model is:

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[2] A store's competitive position may also affect productivity. For their local market, Panel
respondents reported whether their store was the leader with respect to price, service, quality, and
variety. Binary variables indicating leadership in each of these four dimensions were considered
for inclusion in the empirical model, but preliminary analysis showed that they did not add
significantly to explanatory power of the model.

$$lnVAdd_i + \theta VAdd_i = \alpha_0 + \beta_1 \ln SSize_i + \beta_2 \ln TotHr_i + \gamma \sin Z_i \left[\ln SSize_i + lnTotHr_i \right]$$
$$+ \alpha_i EInvoice_i + \alpha_2 SBT_i + \alpha_3 CAO_i + \alpha_4 PGram_i + \alpha_5 FqtShop_i$$
$$+ \alpha_6 SelfDist_i + \alpha_7 Union_i + \alpha_8 \ln PopDen_i + \alpha_9 \ln HHInc_i \qquad (8)$$
$$+ \alpha_{10} Upscale_i + \alpha_{11} FoodDrug_i + \alpha_{12} WHouse_i + u_i$$

Variable definitions are presented in Table 2. Stores with a missing value for any of the explanatory variables in the model were excluded from this analysis. This reduced the sample size to 291 stores. Each observation was weighted by a sampling weight constructed to account for differences in response rates by region and store ownership group size and to correct for over-representation of IGA stores in the sample. Weighted sample means and standard deviations are also presented in Table 2 for each variable in the analysis.

Results

Although unconditional maximization of the likelihood function is feasible for the ray-homothetic function specified in equation (8), a conditional maximization method used by Zellner and Ryu was employed for simplicity and to assist in assessing model robustness. Given a value of θ, the parameters in equation (8) were estimated by least squares and the conditional value of the logarithm of the concentrated likelihood function L^* was evaluated. The values of the parameters including the complete set of { α's, β's, γ, θ } for which L^* is maximized are the maximum likelihood estimates.

Estimates from the most general form of the FJL production function revealed that θ was not significantly different from zero, suggesting that scale economies are independent of changes

in output.[3] Coefficient estimates and t statistics for the sequence of models imposing the

restriction that $\theta = 0$ in equation (8) are presented in Table 3. Due to concerns about

heteroskedasticity, White's correction procedure was used to compute standard errors for

parameter estimates. The reported t statistics are based on these robust standard error estimates.

Model 1 is the full model specified in equation (8). Parameter estimates for the two key

inputs, selling area and labor hours, are both positive. The coefficient for selling area is not

significantly different from zero, but that for labor is highly significant. This reflects the fact that

selling area and labor hours are strongly correlated, making it difficult to separate their relative

effects.

Results from summary income statements of conventional supermarkets confirm the

importance of measuring and valuing the labor productivity in food retailing. The Food

Marketing Institute reported that the most profitable food retailers invested a higher percentage

of expenses in personnel compared to lower performing supermarkets, even though overall

expenses for the top performers were lower than those for the least profitable stores.   Payroll as a

percentage of total expenses was at 47.5 percent for the most profitable stores and 41.9 percent

for the least profitable stores.   High performing stores use managerial skills and operational

methods to control overall expenses more effectively and to maintain high gross margins.

The impact of store size on value-added is potentially masked by other factors.

Occupational costs are typically equal in magnitude to a number of other expenses including

advertising and promotion, utilities, maintenance, and store supplies. By contrast, labor expenses

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[3] Only non-negative values of θ were considered in the estimation process. Negative values of θ
imply an average cost curve with an inverted "U" shape, and the expressions for "optimal" output
actually identifies the level of output at which average cost is maximized.

account for the largest proportion of operating expenses so food retailers would naturally focus on evaluating the role of labor on value-added at the store level.

The estimate of γ – the coefficient of sinZ(lnSSize+lnTotHr) – is positive and significantly different from zero. This implies a production technology that is ray-homogeneous, with returns to scale invariant with respect to the level of output but varying with respect to factor proportions. Of technology adoption variables, only frequent shopper/loyalty card has a parameter estimate that is significantly different from zero at even the 10% level. This suggests that adoption of the information technologies considered in this analysis has little impact on productivity at the store level. Parameter estimates for the two organizational variables, membership in a self-distributing chain and union workforce, are both positive and highly significant, indicating that these characteristics are associated with higher productivity. Parameter estimates for the two Census-based market characteristics, population density and household income, are both positive. However, the coefficient for population density is not statistically different from zero. Finally, none of the parameter estimates for the three store format variables is statistically different from zero. This suggests that the apparent store format effects reported by King, Jacobson, and Seltzer are accounted for by other factors in the model.

In Model 2 we restrict the parameters of the three format variables to be zero. The calculated F-statistic for imposing this restriction on Model 1 is 0.51, which is well below the critical value for even the 90% confidence level. Therefore, the evidence here does not support the hypothesis that format, *per se*, has an impact on store productivity in food retailing. Parameter estimates and significance levels for the other variables in the model are essentially the same for Models 1 and 2.

In Model 3 we impose the additional restriction that parameters of the five technology adoption variables are all equal to zero. The calculated F-statistic for imposing this restriction on Model 2 is 0.97. Once again, this is well below the critical value for any reasonable level of significance. It implies that there is no evidence that these five technologies have any significant effect on store-level productivity. This result is somewhat surprising, given the attention given to these technologies in the supermarket trade press in recent years.

One possible explanation for the lack of productivity effects for these technologies is that stores need time to learn how to use them effectively. If this is true, it should be possible to measure differences in productivity effects associated with time of adoption. The design of the Supermarket Panel will make it possible to measure learning effects in the future, but this is outside the scope of this study.

It is also important to recognize that the first three of these technologies – electronic receipt of invoices, scan-based trading, and use of scanner data for automatic inventory refill – support data and decision sharing with suppliers. The productivity gains associated with these technologies may only be observable at the distribution center level. Those gains can be realized, though, only if the technologies are adopted at the store level. Stores and their primary distribution centers are under common ownership in self-distributing chains, and technology decisions made at the corporate headquarters level should reflect assessments of overall costs and benefits for both supply chain segments. On the other hand, this more comprehensive perspective may be lacking for wholesaler supplied stores. This points to the problem of providing incentives for stores to adopt these technologies when stores and their distribution centers are not under common control.

A third explanation for the lack of measurable productivity measures for the technology variables is that average adoption rates for all five technology variables are higher for stores that are part of self-distributing groups. Therefore, the binary variable for membership in a self-distributing group may be capturing some of the technology adoption effects, as well as effects associated with higher adoption rates for other progressive practices, as suggested by the descriptive results presented in Table 1. This points to the need for further analysis of the factors underlying the positive productivity effect of membership in a self-distributing chain.

Parameter estimates and significance levels for the remaining variables in Model 3 are virtually identical to those in Models 1 and 2. Using parameter estimates from Model 3, it is possible to calculate the returns to scale measure, ε, as defined in equation (6). As noted earlier, this measure can vary with factor proportions, since the expression includes sinZ, where Z is the ratio of selling area to total labor hours. For the wholesaler supplied stores in this study, average selling area is 19,038 square feet and average total labor hours is 1,523 hours per week. The calculated value of ε is 0.988, implying almost constant (but slightly decreasing) returns to scale. For the stores in this study that are part of a self-distributing chain, average selling area is 39,686 square feet and average total labor hours is 2,867 hours per week. The calculated value of ε is 0.985, essentially the same as that for the wholesaler supplied stores. The positive, statistically significant productivity shifting effect for the binary variable indicating membership in a self-distributing group helps explain the difference in store size for these two groups of stores, since an increase in such a productivity shifter increases the marginal products of both store selling area and total labor hours.

Our findings for returns to scale are similar to those reported by Betancourt and Malanoski, who found constant returns to scale with respect to output for a sample of U.S. supermarkets. Their model also measured increasing returns to scale with respect to the provision of distribution services. The evidence on economies of scale presented by Oi in which larger sized stores are driven by lower operating costs are not confirmed by these results.

The positive, statistically significant coefficient for the union workforce binary variable in our model is also noteworthy. Unionization has a positive impact on value-added providing strong evidence that there are productivity gains associated with having a union workforce. This, in turn, provides some justification for higher wages for union workers, since the marginal product of labor, given the levels of selling area and total labor hours, will be higher in stores with a union workforce. Farber and Saks noted that most analytical work on unions has concluded that unions generally raise the mean and lower the dispersion of the wage distribution within firms. Shifts in the intrafirm distribution of earnings due to unionization typically benefit workers at the lower end of the firm's payscale. The wage effects associated with unionization rates apparently have a positive impact on the value-added of food retailers.

Finally, the results for the two Census-based market characteristics, population density and median household income, show that location does matter and that the attractiveness of a location more strongly related to affluence than to population density.

Concluding Remarks

This study presents results from a production function analysis of supermarket operations, using a unique data set from a national survey of supermarkets. We place particular emphasis on

modeling returns to scale using a flexible functional form and on assessing the store-level

productivity effects of information technology adoption. With regard to scale economies, we

find that there are essentially constant returns to scale in food retailing and that there are slight

but statistically significant differences in scale economies associated with differences in factor

proportions. With regard to the productivity effects of information technologies, we find no

evidence of store-level productivity gains associated with technology adoption. We note,

however, that productivity effects from store-level adoption of information technologies that

support data and decision sharing may only be evident at the distribution center level. This may

explain why adoption rates are higher among stores that belong to self-distributing groups that

place stores and distribution centers under common corporate control.

In future work, we will be able to expand the sample size for our analysis by using data

from the 2002 Supermarket Panel, which has approximately 850 participating stores. We may

also be able to assess learning effects for new information technologies by using data from

multiple years and by more fully exploiting the adoption data collected through the Panel.

Finally, we plan to devote added attention to exploring the factors that underlie the strong

productivity gains associated with membership in a self-distributing group, since questions about

the importance of vertical coordination between stores and distribution centers will be critical to

understanding the structural evolution of the supermarket industry.

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Table 1. Store Characteristics and Performance for Stores Grouped by Relationship with Distribution Center[a]

	Wholesaler Supplied	Member of a Self Distributing Group
NUMBER OF STORES REPRESENTED	15,707 (394)	15,578 (167)
MARKET CHARACTERISTICS		
• Median Population Density (per sq. mi)	195	833
• Median Household Income ($/year)	$37,889	$42,594
• Percent Located in an SMSA	55	77
STORE CHARACTERISTICS		
• Median Store Age (years)	25	17
• Median Number of Stores in Store Group	3	265
• Median Weekly Sales	$125,000	$318,000
• Median Selling Area (sq.ft.)	20,000	38,000
• Percent with Union Workforce	18	41
MANAGEMENT SCORES (Median)		
• Supply Chain	45	80
• Human Resources	37	45
• Food Handling	85	92
• Environmental Practices	50	83
• Quality Assurance	55	81
• Service Offerings	38	46
PERFORMANCE MEASURES (Median)		
• Weekly Sales per Square Foot	$7.00	$7.83
• Sales per Labor Hour	$96.00	$124.07
• Sales per Transaction	$17.25	$23.81
• Annual Inventory Turns	17.0	16.0
• Percentage Employee Turnover	42.9	44.1
• Gross Profit as a Percent of Sales	23.7	24.1
• Payroll as a Percent of Sales	10.0	9.7
• Annual Percentage Sales Growth	2.9	3.2

[a] Source: King Jacobson, and Seltzer, p. 66.

Table 2. Variable Descriptions and Summary Statistics

Variable	Description	Mean	Standard Deviation	Survey Question[a]
VAdd	Value-added ($/week)	$70,072	$62,570	Q50, 52
SSize	Store selling area (square feet)	31,364	17,745	Q8
TotHr	Full-time and part-time labor (hours per week)	2,385	1,581	Q21
EInvoice	Electronic receipt of invoices from vendors/suppliers, 1 if yes, 0 if no	0.563	0.497	Q1d
SBT	Scan-based trading, 1 if yes, 0 if no	0.253	0.435	Q1n
CAO	Scanning data used for automatic inventory refill, 1 if yes, 0 if no	0.131	0.338	Q1o
PGram	Shelf-space allocation plan-o-grams, 1 if yes, 0 if no	0.745	0.437	Q1p
FqtShop	Frequent shopper/loyalty card program, 1 if yes, 0 if no	0.410	0.493	Q6h
SelfDist	Membership in a self-distributing group, 1 if yes, 0 if no	0.496	0.501	Q15
Union	At least 25% of employees covered by a collective bargaining agreement, 1 if yes, 0 if no	0.266	0.443	Q25
PopDen	Population density in store's zipcode (people/square mile)	1,248	1,767	US Census
HHInc	Median household income in the store's zipcode ($/year)	$44,824	$16,732	US Census
Upscale	Upscale format, 1 if yes, 0 if no	0.074	0.262	Q30
FoodDrug	Food/drug combination format, 1 if yes, 0 if no	0.240	0.428	Q30
WHouse	Warehouse format, 1 if yes, 0 if no	0.046	0.210	Q30

[a] The question number in the 2001 Supermarket Panel Annual Report, corresponding to each variable. See text for more information on survey response categories.

Table 3. Estimation Results

Variable	Model 1		Model 2		Model 3	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Constant	-0.040	-0.047	-0.224	-0.279	-0.262	-0.339
lnSSize	0.031	0.447	0.031	0.430	0.036	0.534
lnTotHr	0.934	12.716	0.952	13.902	0.947	13.568
sinZ * (lnSSize+lnTotHr)	0.004	2.054	0.003	1.936	0.003	2.145
EInvoice	-0.027	-0.441	-0.020	-0.323		
SBT	-0.061	-0.939	-0.057	-0.888		
CAO	0.007	0.083	0.015	0.181		
PGram	0.062	0.873	0.052	0.736		
FqtShop	0.079	1.675	0.075	1.609		
SelfDist	0.239	3.937	0.228	3.834	0.233	4.819
Union	0.155	2.797	0.149	2.731	0.167	3.118
lnPopDen	0.020	1.416	0.020	1.382	0.021	1.493
lnHHInc	0.294	3.639	0.301	3.856	0.306	3.968
Upscale	0.107	1.054				
FoodDrug	0.005	0.085				
WHouse	0.086	0.695				
R²	0.8989		0.8979		0.8955	