EXPLAINING PRODUCTIVITY DIFFERENCES IN GROCERY WAREHOUSES

William Lesser
Vaughn Roller*

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*Assistant Professor and Graduate Research Assistant, respectively, in the Department of Agricultural Economics, Cornell University. Paper presented at the Conference on Productivity in Distribution, Ithaca, NY, October 16-17, 1981. This research was supported by Hatch projects 412 and 443.

INTRODUCTION

Urban renewal in Boston and other older industrial cities has taken advantage of sturdy old warehouse structures which can be converted into attractive homes, shops and offices. Our concern here, however, is addressed not to the new tenants of these facilities, but to the original ones. These operators have long since moved into modern, one-story buildings on the outskirts of dozens of cities across the country.

These moves are but minor examples of the dynamics of our capital intensive economy. Regrettably, these examples have not always been as successful as desired. Considering only a subset of the total warehousing sector, the food distribution center, productivity has lagged in recent years while costs continue to increase. Kochersperger has found productivity to be essentially flat from 1968 through 1977 while wages rose by over 100 percent (1978, p. 59). In this labor intensive industry where labor is estimated to compromise 50 to 80 percent of total costs, (Progressive Grocer; Grinnell and Crawford 1977, p. 15), the effect has been higher total costs. Thus, the food distribution center operation which was estimated to add 2.5 percent to the retail cost of food in 1968 is now seen as commanding an increasingly larger share (Kaylin 1968, p. 13; Ray 1975).

The resulting effect on retail food prices is an ongoing concern for officials inside and outside the food industry. Public policy analysts see distribution center costs as contributing to the spiraling farm-retail margin which in 1980 rose more than twice as fast as the farm share of the $6.7 B spent for at home food consumption (Progressive Grocer 1981, p. 66). Food industry executives for their part are concerned with the high cost of distribution centers. Savings there could materially enhance the profitability of food chains which typically have net earnings of under one percent of sales (German and Hawkes 1980). Among industry officials concern is particularly acute for

those whose productivity is poor compared with the norm. Physical productivity has been found to vary by an astounding 300 percent for a sample of operations (Cornell Report 1980, p. 7). Indeed, 78 percent of food industry executives responding to a national survey intend to meet the expected requirements for additional food warehouse space through enhanced productivity rather than the construction of new facilities (Harris and Stevenson 1980, pp. 37-39).

Evidence of potential physical productivity improvements exists. Physical productivity standards developed for many warehouses show that 10 percent reductions in costs can be achieved without new investments or major organizational changes (Wolff 1980, p. 43). Grinnell has also found that organizational changes can improve the productivity of existing warehouses by up to 40 percent. Yet firms have found this information difficult to act on. One Midwestern chain, for example, had performance standards established which showed many workers operating at only 60 percent of the standard. Several years later management is still looking for means of improving performance levels.

Partially, the poor productivity record of food distribution centers can be attributed to past neglect during a time when they were treated by retailers as ... "huge buildings where no money [could] be made" (Kochersperger 1978, p. 69). Now that attitude is changing at a bewildering pace. Distribution executives aware of the need to improve productivity remain uncertain how to proceed and which aspects to modify first. Essentially this demonstrates a basic lack of understanding of what are the significant factors causing high (or low) warehouse productivity.

The purpose of this paper is the identification of operating characteristics associated with higher productivity in grocery distribution centers. The delineation of these characteristics will assist warehouse managers in deciding which aspects of their operations to consider first in productivity improvement efforts.

The analysis is limited to physical productivity in conventional dry grocery distribution centers. Presently conventional distribution centers, which are most easily identified by the absence of automated selection equipment such as an Ordermatic or Rapiston system, account for 98 percent of all grocery warehouses. Within these operations labor as mentioned accounts for over 50 percent of total costs. Therefore, by limiting the analysis in this way we have focused the results on the largest potential clientel group. Moreover, although the analysis addresses only food distribution centers the characteristics of numerous other warehousing operations are similar enough so that the insights developed here can also be relevant to this broader group. This analysis nevertheless is the first of its type in this area and the results should be viewed as indications only of how physical productivity could be improved. A detailed analysis on a facility-by-facility basis should be made before the recommendations presented here are applied to any particular warehousing operation. Such analyses should further consider that labor productivity is only one component of warehouse costs, and enhancing productivity will not necessarily reduce total operation costs in either the short or long run.

Distribution Center Functions

The following discussion is by necessity somewhat technical. A brief description of distribution center operations will clarify the discussion.

The food distribution center is in essence a break bulk operation, receiving relatively infrequent large shipments from manufacturers and wholesalers and shipping frequent loads of a large variety of products in small volumes to retail outlets. To accomplish this function, the warehouse must receive products, position them in such a way that individual store requirements can be selected and compiled for loading and distribution to retail

outlets. Five functional areas in the warehouse encompass these activities: (1) receiving (truck and rail), (2) storage, (3) replenishment, (4) order selection, and (5) loading for shipment.

Receiving includes coordinating incoming shipment schedules, unloading trucks and rail cars and preparing stock for storage. Movement within the warehouse is by such mechanized equipment as pallet jacks and fork lift trucks which require that merchandise be loaded on pallets. If incoming products are not so arranged, that is, unitized, the individual cases must be placed on pallets by warehouse or carrier personnel. From the receiving dock, products are moved to storage locations where they remain until required for filling store orders.

Store orders are selected or "picked" in distinct areas of the warehouse. Personnel travel through the aisles selecting or "picking" the required number of cases from selection slots to make up individual orders. Picking several orders simultaneously is known as batch picking. The movement of products from storage to selection slots is referred to as replenishment. Replenishment is highly variable from operation to operation due to differences in storage locations (above the selection areas vs. separate parts of the warehouse) and designation of specific replenishment responsibilities compared with replenishment on call. Combined, storage, replenishment and selection use most of the labor in a warehouse, about 65 percent of direct labor (Kochersperger 1979, p. 2).

After picking, the order is consolidated and loaded into delivery vans. Loading may be done in palletized (unitized) form and/or by individual carton if loads are not unitized. These activities which constitute the shipping operation are carried out on the shipping dock. Shipping and receiving may be done from the same dock or from two separate dock areas.

Besides the physical handling of the products, labor is used to check the products as they arrive and again during shipping. The clerks who carry out these checks are counted as part of the direct labor in a warehouse. This separates them from the support of indirect labor which consists of sanitation, security and maintenance workers.

One final distinction needs to be made. Technically, there is a functional difference between warehouses and distribution centers. Warehouses are for inventorying products while distribution centers are break bulk operations used to prepare loads for retail shipments. These differences are important for the number of items handled and for the length and form of storage in these two types of facilities. However, in the interest of textual simplicity the two terms are used interchangeably herein.

FACTORS INFLUENCING WAREHOUSE PRODUCTIVITY

Several procedures have been used in the past to determine factors affecting distribution center productivity. Most common of the procedures is engineering-economic analysis, although other techniques such as production function and cost curve analyses have also been employed. This material along with observations by industry experts is reviewed here and used to develop a model for subsequent analysis. (For a related discussion see Roller and Lesser.)

Physical Characteristics

Facility Size: Several researchers have found a direct relationship between warehouse size and physical productivity, measured as cases per hour of direct labor. Pierson estimates a 32 percent increase between warehouses shipping 80,000 cases a week and those shipping 400,000 cases a week, when both are operating at 100 percent of capacity (1972, pp. 68 and 73).

Crawford and Grinnell's estimate is far more modest -- a 4 percent increase between warehouses with outputs of 100,000 and 500,000 cases per week (1976 p. 12). Given that the operation of a warehouse consists largely of individual tasks during storing, selecting, etc., larger warehouses essentially increase the number of these functions which are operating simultaneously. Thus it might be expected that size efficiency would be at best modest, certainly not on the order estimated by Pierson. In fact, Pierson's estimated time savings are traceable to the larger number of cases per pallet load as warehouse size increases. This number more than doubles from 22 for the smallest to 49 for the largest warehouse in his estimate (1972, p. 68). Under these conditions productivity is certain to increase with warehouse size since much labor time is spent handling full pallets from receiving to storage and from storage to selection. The larger number of cases per pallet is related to the assumed use of predominately small pallets in the smaller warehouses and larger pallets in the larger ones (1972, p. 39). This assumption is suspect for current operations in which the use of large pallets is nearly universal.

Thus Pierson's estimates do not provide very convincing evidence of the existence of size efficiencies in warehousing. Indeed, at the upper end of his size range, 360,000 and 400,000 weekly case throughput, productivity begins to decline slowly, down to an average 78.5 cases per hour from 79.3 cases per hour (1972, pp. 68 and 73). If this indicates a facility size at which productivity begins to decline it could severely hinder large operations. The largest warehouse used in Pierson's analysis, 267,203 square feet, is only medium size by current industry standards. The 1980 Cornell Report, for example, includes one of 525,000 square feet, almost twice as large. Such a negative productivity relationship with size for larger

warehouses seems plausible considering the greater distances which must be traveled in the warehouse.

The Crawford and Grinnell analysis also raises some questions about the appropriate relationship between size and labor productivity. Their estimated 4 percent productivity increase from the smallest to largest warehouse is realized totally in receiving; in the other functional areas productivity is uniform across warehouse size (1976, p. 12). No explanation is given for the estimated productivity increases in receiving. In fact, if larger warehouses have greater backhaul opportunities, receiving productivity could be reduced as backhaul is always unloaded by warehouse labor while the carrier unloads many of the scheduled deliveries. Efficiencies attributable to specialization of personnel could be relevant for the smallest warehouses. But beyond that most warehouses have personnel assigned to a single functional area or to closely related areas such as selection and shipping. There is no clear advantage to specialization beyond this level.

These two studies may have produced questionable results because they were based on the economic-engineering estimation techniques. This procedure requires among other steps the development of labor performance standards. Such standards are relatively easy to establish, and relatively accurate, in a capital intensive operation where the pace is determined by the equipment which is under the control of management. In a meat-packing plant employees not working up to chain speed are readily detected. For labor intensive operations where the work pace is determined largely by the individual and whatever effective management can be brought to bear, the procedure of establishing labor performance standards is far more complex and subject to errors. Once estimated the standards are often entered in the analysis as constants, thus failing to account for distance factors or coordination and

control problems as the size and number of employees increase (French 1977, p. 140).

The problems with applying the economic engineering approach appear to be particularly acute for a highly labor intensive operation such as warehousing. As a case in point, a warehouse operation director familiar with a warehouse actually built to the specifications used for the Pierson study reports that it has never achieved the specified productivity levels (McNabb). Hence, the overall evidence on positive size productivity relationships in warehousing is weak, while a slightly negative effect seems more likely on logical grounds.

Number of Items Handled: In recent years there has been a rapid and accelerating increase in the number of items introduced into retail food stores. For the ten year period 1969-78 a total of 18,310 items were introduced, almost 3,000 of these in 1978 alone (Progressive Grocer). Not all of these were added by individual stores and many replace other items, while others have a brief life. Nevertheless, the overall effect has been a significant increase in the number of items carried in distribution centers - an increase that reduces labor productivity (Grinnell and Crawford 1977, p. 19).

The principal cause of reduced labor productivity is the increase in the number of slow-moving items. Slow-movers typically are located in remote areas and require increased transport time. Some require repacking, a labor intensive process of opening cases and shipping less than case load volumes. As a result, warehouses carrying larger numbers of items are expected to be less productive.

Crowding: Associated with the rise in the number of items and general increases in volume is the overcrowding of many warehouses. "The level of productivity drops when warehouse aisles become cluttered and warehousemen receiving merchandise must make room for the incoming merchandise by

repiling and stacking merchandise in the aisles or on the dock" (Bauma and Kriesberg 1960, p. 27). This situation has become more critical in recent years as management has become increasingly reluctant to invest in additional distribution capacity.

Use of a Single Dock: Warehouses with a single dock for both receiving and shipping are almost certain to experience congestion and delays unless the operations are scheduled for different shifts. Orders piled on the dock can nonetheless hamper operations so that warehouses with single docks are expected in general to have lower labor productivity than those with separate shipping and receiving docks.

Physical Operations

There are a number of interrelated aspects of the physical operations which significantly effect productivity. It is not possible to discuss in detail each of these, but those identified most frequently in the literature will be reported.

Automation: Automation in the distribution center refers to the use of automatic selection equipment such as the Rapistan or SI Ordermatic. These systems generally enhance the productivity of this activity, which is the most labor intensive within the warehouse (Chain Store Age Executive 1975, pp. 11-12). Crawford and Grinnell estimate a 200 percent or greater increase in selection productivity over a similar conventional operation. Considering all warehouse functions, the estimated productivity increase is substantially less -- only 40 percent -- because labor requirements for replenishment are increased with automated systems (1976, p. 12). Crawford and Grinnell's estimates, however, overstate the labor savings attributable to automation because they assume 80 percent of the volume can be selected through these systems while experience has shown the actual amount is closer to 50-60 percent.

In fact, the Cornell Report contains data on conventional operations that post higher selection productivity than automated systems (1980, p. 34). Thus, while automation can improve productivity over what it would be otherwise it does not necessarily have this effect.

Batch Picking: Batch picking, the simultaneous selection of multiple orders, increases labor productivity by reducing the number of times warehouse personnel must traverse an aisle (Crawford and Grinnell 1976, p. 12).

Unloading and Loading: The receiving and shipping operations require about 25 percent of warehouse labor, although this is highly variable depending on how products are received and who does the unloading (Kochersperger 1979, p. 2). If the trailers are unloaded by the driver, as is the practice for common carriers, no warehouse labor is required. Backhauls and some other private carrier delivered shipments must be unloaded by warehouse personnel. When products arrive nonpalletized, this operation must be done by hand, a time consuming operation. Rail freight, which arrives palletized, on slip sheets or floor loaded is always unloaded by warehouse personnel.

Similarly, loading is done by warehousemen. A greater number of orders per load can reduce productivity as it makes the staging and loading operation more involved. In recent years some firms have been trying to minimize transport costs by filling their delivery vehicles completely. This necessitates closer planning as well as some hand loading.

Repacks: Repacking is a labor intensive operation as individual cases must be opened and portions selected and repacked for shipment. Warehouses which handle a larger number of repacks require more labor than those with fewer repacks.

Storage, Replenishment, Selection and Loading Practices: Among the 10,000 plus items handled by a typical large supermarket there is considerable variability in movement frequency.

Placing the faster moving items closer to the docks reduces travel time, thus enhancing productivity. The use of floating storage and selection slots also reduces travel time by allowing the lift operators to use the nearest available space (Kochersperger 1978, p. 119). The increased complexity of floating slot systems, however, necessitates some form of computerized space control. Typically computerized operations use computer generated case labels designating the proper slot. Experience has shown, however, that these systems vary significantly in degree of sophistication. When fixed slots are used the lift operators' memory is often sufficient for locating the proper spaces. Such a system is simplified if items are stored by family groups.

Replenishment is sometimes referred to as the forgotten area of warehouse operations. It is widely believed in the industry that a large majority of warehouses replenish at the request or "call" of order selectors. This practice may result in waiting time and congestion as the two activities are coordinated. However, among 20 warehouses in the 1980 Cornell Report which reported replenishment operations, only 31 percent were in response to order selection demand. Overall 90 percent of the cases entering these warehouses were rehandled in a replenishment operation (1981, p. 29).

Shipping involves the consolidation of orders from the selection area on the dock for checking and for loading into trailers. This may be done directly by the order selector or in stages with the selector depositing the pallet on the dock for subsequent movement by dock personnel into a trailer. In an earlier analysis we found the direct movement to be more labor efficient, possibly because of reduced congestion and coordination problems (Lesser and Roller 1980, p. 156).

Labor

In any labor intensive limited skill operation such as warehousing, the motivation of the workers is the key to high productivity. Yet with repetitive tasks and little opportunity for advancement for warehousemen there is little incentive to perform well. One executive stated the situation succinctly (Supermarket News 1970):

> Order picking has to be one of the worst jobs in the world. This guy has to go around the warehouse all day picking out cases -- and it has no meaning for him. No wonder he does a lousy job.

In fact, a major attribute of mechanized selection systems is that they, not the individual warehouseman, determine the rate of activity for the entire operation (Chain Store Age Executive 1975, p. 11). And automated equipment does not require motivation.

The way in which labor is managed and the interaction of management style with employee abilities and union agreements will be major determinants of the productivity of individual distribution centers. Other analysts have recognized the importance of labor management but have failed to identify specific means of enchancing productivity through improved management (cf. Grinnell and Crawford 1976, p. 12). For the current analysis we wish to discuss labor as two interrelated components referred to as effective quality and management practices.

Effective Quality: Effective quality refers to the degree to which warehouse personnel work to the extent of their ability within the environment of an individual warehouse. Effective ability is influenced by several factors, including general ability as determined by personal characteristics (e.g., strength and intelligence) modified by education, job training and experience. Although warehouse work is generally unskilled, training and experience are important for learning the tricks necessary for continued high productivity. Basic literacy is essential, while higher intelligence can be

helpful if it enhances judgment in organizing and coordinating tasks. Teamwork developed through practice can assist in the coordination of such interfacing functions as receiving and storing, or selection and shipping.

Because of the importance of experience and team work, interruptions caused by frequent absenteeism or high turnover rates can disrupt operations and reduce productivity. These disruptions can also be symptomatic of deeper labor problems and are often most pronounced in the second and third shifts. Management has continual problems finding reliable workers for these less desirable shifts so that warehouses operating multiple shifts frequently suffer lower productivity.

Unions are a dominant force in warehousing, particularly in the older industrialized areas of the Northeast and Midwest. Unionization has ambiguous effects on warehouse productivity for three primary reasons. First, the local has particular significance as many of the contract agreements on work rules are decided at the local level. Thus, the major impact of unionization may not be seen as much between union and nonunion operations as between certain traditionally unionized regions compared with others, both unionized and nonunionized. As a rough rule, the longer a warehouse has been unionized the more significant will be the influence of unionization. As a result warehouses in the Northeast, where unions have been a factor for a number of years, are generally considered to be less productive than recently unionized centers in the South (McNabb).

A second effect of unions is the relationship between work rules and on-the-job training. Seniority based systems, typical among warehouse contracts, foster training by reducing competition among workers. On the other hand, the same system allows promotions based on seniority rather than on performance and, during periods of curtailment, bumping. Bumping typically

replaces a trained worker with an inexperienced one, while seniority-based promotion reduces the incentive to excel. Restrictive work rules such as prohibitions on the use of particular pieces of equipment for categories of workers and minimum guaranteed work hours diminish the flexibility of management and overall are seen as reducing productivity (cf. Brown and Medoff 1978, pp. 357-60).

The third primary effect of unions is that they contribute directly and indirectly to supervision. This can come about in several ways. First, by increasing workers' feelings of control through the use of a formalized grievance procedure, motivation can be improved. Moreover, workers in a noncompetitive environment can be more willing to cooperate among themselves in the spirit of soliderity and identity which is frequently characteristic of strong unions. Both motivation and cooperation are significant in warehousing. Second, unions have been effective in explaining changes in the day-to-day routine to workers (Bok and Dunlap 1970, p. 262). Thus adjustments in scheduling may in fact be easier to implement in a unionized than in a nonunionized warehouse.

It is currently popular in a number of circles to blame unions for a significant part of the inefficiencies and costs in the US industrial sector. In some cases these charges seem appropriate, and some warehousemens' locals could probably be included among these. Management must nevertheless acknowledge a share of the responsibility for the current state of union agreements. Perhaps the most devastating event in one's working life is to be laid off. The financial and emotional toll of this practice is enormous for the average worker. In response, unions have made job security a central part of labor agreements and the powerful ones have been successful at providing protection for at least the more senior workers. This response on

their part is entirely understandable. The effect of firmly entrenched seniority rules has nevertheless often been a proliferation of work rules and standards which have the side effects of limiting management control and adversely affecting productivity.

Management for its part has apparently chosen to exchange some supervisory flexibility for the opportunity to lay off workers when situations require. This may have been a dubious choice as the cost of operating under restrictive agreements could exceed that of keeping temporarily unneeded workers on the payroll. The lifetime employment practice as followed by many Japanese firms might foster better cooperation between management and labor. Cooperation is essential for achieving the required flexibility needed to manage the varying requirements of a distribution center. The antagonistic relationship between labor and management seen in many warehouses and throughout much of the economy is inimical to efficiency.

Much of the basic relationship between unions and management was formulated outside warehousing and transferred to it. Also there is not always an obvious exchange in negotiations between job security and management flexibility. The fact nevertheless remains that the prevailing labor practice in the US of furloughing workers contributed to the development of a system which management now finds difficult to cope with. Corrective steps should come through recognition and compromise by both sides, not by means of retrenchment and power struggles.

Management Practices: Management can be described as administering labor through a combination of direction and incentives. Direction relates to task identification and supervision while incentives include both positive and negative actions.

A typical incentive provided to workers to attract more productive individuals is higher pay compared with competing opportunities. In the unionized warehouse, however, the use of this option for existing employees is often limited by contract stipulations restricting wage incentives for high productivity. Management nevertheless retains the option in most cases of providing time off with pay for outstanding performance, while in other situations management may use gifts like color televisions in recognition for high performance. Such approaches provide direct and highly visible incentives for achieving high productivity levels. Neverthless, few warehouse managers make use of this opportunity (Cornell Report 1980, p. 32).

If pay and bonuses are the rewards for improving productivity, the punishment is disciplinary procedures leading up to and including discharge. These procedures are most effective if related to some performance standard such as those established through industrial engineering analysis. Inadequate performance compared with these standards would warrant a warning, hearing, etc. up through discharge. The cooperation and involvement of firm management and union leadership is critical in this procedure.

Finally, direction must be provided by lower level management, particularly at the first-line level. The responsibilities of these managers are significant, including assigning tasks, checking for completion, handling interpersonal relations and anticipating and responding to problems. While most managers have these duties, they are simply more difficult and important in the relatively unstructured and tedious warehouse environment. As a result, higher level management should pay greater attention to the qualifications and training of the first-line supervisors. Yet the opposite appears to be true. Only recently have the salaries of distribution managers been approaching those of other area managers (LaLonde 1975, p. 7). First-line

supervisors often receive lower salaries than the men they are supervising when average overtime is included.

Supervisory levels are also significant, although determining the proper ratio is difficult. One writer has suggested a ratio for all distribution centers of one first-line supervisor for six direct workers, or a ratio of .17 (Delaney 1975, p. 620). This ratio may not be exactly appropriate for grocery warehouses but should be roughly comparable. Yet the supervisory levels reported in the Cornell Report are always lower than this, ranging from .14 down to .04 (1980, p.11). If Delaney is even approximately correct then many food distribution centers are decidedly undersupervised.

Distribution of first-level management across the functional areas is even more varied in food distribution centers. Relatively more supervision is given to truck receiving where some centers have a supervisor for every three workers. In order selection the supervisor/employee ratio varies from .32 to .01 with a mean of .035 (Cornell Report 1980, pp. 18 and 37). In other words, some selection activities operate virtually unsupervised despite the large amount of discretion possible for the workers. Supervisory levels show no obvious relationship to the size of the warehouse even though jobs and the supervisors who oversee them would be more specialized in the larger warehouse, possibly necessitating lower supervisory levels (Lesser and Roller 1980, p. 12).

EMPIRICAL ANALYSIS

At a first glance, warehousing productivity seems well suited to production function analysis. Warehouses combine capital in the form of the structure and rolling stock with labor to produce a product -- a case loaded into a truck for delivery. The estimation of a model using multiple regression procedures would provide information on the contribution of each of the factors to output.

The appeal of this procedure quickly fades under further scrutiny. Problems appear in both data availability and measurement. Capital investment data are particularly difficult to assemble given the range of ownership and leasing arrangements for the structure and equipment. The myriad of small differences in operating characteristics, including such factors as facility size, crowding, use of batch picking, etc., tend to be interrelated, complicating the interpretation of results. Most significant is the problem of including variables which measure management quality. Much production function analysis omits management quality variables, but this seems inappropriate for warehousing where management is a key factor in the relative productivity of different operations.

Previous attempts by the authors confirmed the complexities of estimating production functions for warehousing. Although managerial quality variables were difficult to measure in this case as they were elsewhere, estimates that excluded managerial quality produced little interest. The expedient of using a number of related or contributing factors -- proxies -- increased interpretation problems by creating multicollinearity. Yet, while the significance of each coefficient was low, the proportion of explained variance was high, indicating that there were relationships to be uncovered if the proper procedure could be identified.

The procedure used here is factor analysis. Factor analysis is appropriate as it is "based fundamentally on the faith that the observed correlations are mainly the results of some underlying regularity in the data" (Nie et al., 1972, p. 471). That is the hypothesis underlying this analysis -- the existence of a limited number of basic factors or conditions which explain the sharp productivity differences observed among dry grocery distribution centers. The purpose of this analysis is the identification of those common determinates.

The value of factor analysis is its ability to reduce the number of variables to a smaller group of characteristics which continue to account for a substantial portion of the observed relations in the data. The process of factor analysis is therefore inherently different from regression. In regression analysis the interest is measuring the independent effects of the preselected explanatory variables on the common or criterion variable. In contrast one use of factor analysis is identifying types (Comrey 1973, pp. 242-44). In the present study the interest is in identifying types of management and physical characteristics common among the more productive warehouses and comparing these with the less productive ones. From another perspective this is an exercise in taxonomy -- the classification of warehouses according to productivity levels based on specific managerial and physical characteristics.

The advantage of factor analysis applied to warehousing is the reduction from a large number of potentially contributary factors to a smaller number of critical ones. This then leads to a clearer insight into the relevant factors and interactions among them, an insight aided by the reduction in the number of variables under consideration. As a taxonomic exercise, the principal benefit of the factor analysis as employed here is the identification of the relevant variables to analyze and measure in future research. Thus it serves as an important first step in a more detailed analysis of distribution center productivity.

There is a persistent controversy among statisticians and social scientists concerning the interpretation which can be given to factors. In brief the controversy can be reduced to a question, are factors real? That is, do they correspond to some underlying relationship which has been illuminated through the factoring process, or are factors simply the results of mathematical manipulations which cannot be expected to have meanings beyond the

demonstrated statistical relationships? (Comrey 1973, pp. 227-29). The answers lie outside the scope of this paper, but the question does reflect the importance of how the factors reported here are to be interpreted. On this point several comments are appropriate. The variables entered into the analysis and the hypothesized interrelationships among them as discussed below are based on prior analysis using a range of techniques and data. Thus the analysis is akin to a model-testing procedure. The statistical measures of the goodness of fit of the model are, however, looser than those available for other forms of investigation such as regression analysis. Particularly critical is the name or description given to each of the identified factors. Such a procedure is inherently judgmental, but the title selected does have a critical effect on how the factors are viewed. Contributing to the judgmental nature of the results is the fact that during analyses repeated estimates were made on the same data while only the best results in the sense of internal consistency and agreement with expectations are reported. While this procedure is common in empirical analysis it does weaken to a degree the confidence in the results, whether that confidence is based on strict statistical tests or beliefs in the emerging underlying relationships among the data.

Despite this, the results are consistent with previous analyses and our own a priori expectations. Furthermore, they appear reasonable. The central issue then is how these results are to be applied. They should prove useful to researchers in the area of food distribution who are attempting to identify the important variables for analysis. The results should also provide important insights to warehouse management personnel attempting to understand the underlying factors contributing to the productivity of their operations. Finally, the analysis provides additional views of how unionization influences productivity. The application of factor analysis to firm-level data makes

possible a more precise delineation of the means by which unionization influences productivity than has been possible with cross-industry production function analysis (cf. Brown and Medoff 1978, p. 375).

Source of Data

Data were drawn from the 1979 and 1980 editions of the Cornell Report on Productivity in Grocery Distribution Centers. Thirty-eight participants in the report, retail food chain and wholesaler warehouses, submitted operating data from the same four-week period in at least one of those years. Operating conditions were considered to have remained sufficiently consistent over that period to allow a simple pooling of the data, which were collected and reported in three broad areas: physical characteristics of the warehouse (size, ownership, location), management related factors (unionization, supervisory levels, wages, incentive systems, inventory systems), and productivity related variables (cases, tons, manhours).

Participation in the report is on a voluntary basis so that the warehouses included do not necessarily represent a random-sample of dry grocery warehouses in the United States and Canada. Nevertheless the sample does show significant size variability which spans both the smaller (30,000 sq. ft.) and the larger warehouses (525,000 sq. ft.) in operation. Ownership type in the sample is less varied with integrated chain warehouses heavily dominant over wholesaler and cooperative distribution centers. These facilities are nevertheless operated in very similar ways by all three groups. Although no obvious distortions are apparent, some consideration to the representativeness of the sample must be given when interpreting the results. Moreover, some of the results do reflect chance characteristics of the sample rather than important underlying relationships. These are discussed below.

Because the data collection function was coordinated independently by an employee at each warehouse, some variability in the quality and quantity of data was expected. Differences in warehouse information systems, enumerator skill and motivation and even labor contract restrictions contributed to some degree of measurement and omission error in the data initially recorded on returned questionnaires. To improve data integrity a follow-up was undertaken to complete questionnaires and then to verify, correct or delete questionable entries. Detailed computer-assisted screening, employed as a last quality assurance check before publication, resulted in the deletion of some observations. This editing coupled with anomalies in the sample (e.g., no rail receiving in one warehouse) caused disparate subsample sizes, 32 inbound and 29 outbound observations out of 38 participants.

Despite the precautions taken some information proved more difficult to collect than other and errors may remain, influencing the reported results of the analysis. Information which proved to be particularly difficult for the responders to compile accurately were such operating characteristics as the allocation of time between interfacing operations such as receiving and storing. For this reason the analysis combined the five functional areas into two nonoverlaping functions: inbound (receiving and storing) and outbound (selection and shipping). Data on replenishment were particularly sketchy and were omitted. Also, some questions proved to be very difficult to phrase clearly. One example relates to the crowding in a warehouse, an important factor as it could lead to congestion and lower productivity. As one measure respondents were asked to estimate capacity and current inventory, but capacity figures proved sketchy and unreliable. Another measure, the use of the receiving dock for storage, is a proxy since surplus items in a crowded warehouse often end up on the dock. Some warehouses, however, receive

infrequently by rail and could use this area between receipts without hampering operations. As a result some variable specific variance was introduced into the analysis.

Factor Models

In modeling the operations of food distribution centers the researcher must address two questions: (1) What is the appropriate level of aggregation given the data and the nature of warehouse functions and, (2) What are the underlying factors which determine the level of efficiency at which economic inputs such as capital and labor are applied?

Data from the Cornell Reports were collected and detailed for each warehouse at the level of several subtasks: truck and rail receiving, storing, selection, slot replenishment, order selection and shipping preparation. This represents the greatest possible degree of disaggregation in the data and therefore in model specification. Problems of interfunctional time allocation and measurement of intra-warehouse movements mentioned above ruled out this level of detail of the analysis. As an alternative aggregates into inbound and outbound operation were employed.

In general the factors for both inbound and outbound operations fall into two broad groups -- physical characteristics and management. Physical characteristics include facility size and a potentially large number of operating cheracteristics such as crowding, inventory policies, use of batch picking, etc., each of which has an expected effect on productivity. These variables are expected to load onto two factors, one describing the particular characteristics of the warehouse and the other describing its size. However, given the mixed evidence on the effect of size on productivity it is likely that the loading on this latter factor will be small.

Management may be subdivided into pratices followed in warehouses with and without strong union locals. Thus, management should load on two factors. The management domination factor is expected to show a positive relationship to productivity while the union-domination factor may be either positively or negatively associated with productivity.

Inbound Variables

Previous analysis combined with a detailed knowledge of the food warehousing industry led to the specification of the following variables as important explainers of inbound productivity. All data, unless noted otherwise, are from the Cornell Report.

1. Labor Productivity (INCMH): designated as cases per man hour; measures physical productivity.
2. Physical Plant Size (FLAREA): square feet; indicates the effect of size on productivity.
3. Number of Items Carried (ITEMS): a greater number of items implies more slow movers, thus more labor per item.
4. Number of Repack Items Carried (REPACKS): items sold in less than case quantities results in more handling and lower productivity.
5. Receiving Hours (RECHRS): total truck and rail receiving hours per week provides a temporal measure of capacity utilization.
6. Size of Dock Facilities (DOCKPCT): receiving dock share indicates adequacy of staging area of warehouse space.
7. Backhaul Percent (PCTBH): more merchandise received on warehouse delivery trucks requires more warehouse labor for unloading.
8. Portion of Unloading Done by Warehouse Employees (TRUNLOAD): increased carrier unloading reduces warehouse labor and therefore increases productivity.
9. Importance of Rail Relative to Truck Receiving (TRRATIO): rail cars are always unloaded by warehouse personnel; a higher proportion of rail to truck receipts means lower productivity.
10. Use of Docks for Storage (DOCKSTOR): potential warehouse crowding.
11. Storage Density (STORDENS): units stored per square foot.

12. Checking Procedures (CHECK): close checking slows inbound process.

13. Inventory Turnover (INVTO): monthly physical inventory turnover; lower turnover indicates greater investment and potential crowding.

14. First Level Supervisory Span of Control (INSPAN): ratio of hourly employees to foremen; ceteris paribus, greater supervision improves production through better coordination and less employee laxness.

15. Employment Turnover-Warehouse Labor (HRTO): portion of warehouse labor voluntarily or involuntarily terminated annually; affects productivity positively or negatively through inexperienced workers hired or inefficient workers discharged.

16. Employment Turnover-Supervisors (SUPTO): portion of the warehouse supervisory staff terminated annually; high supervisory levels may mean poorer productivity with less experienced supervisors or reflect deep labor problems.

17. Unionization (UNION): labor organization status in each warehouse; effects are ambiguous.

18. Ownership of the Warehouse (OWNER): wholesaler, integrated retailer or retailer coop owned (1 = nonintegrated). Evidence is weak for the belief that wholesalers with greater financial stakes in distribution are more efficient.

19. Absentee Rate (ABSTP): ratio of unscheduled absent hours to total labor hours; absence impedes coordination, reducing productivity.

20. Overtime to Total Hours Ratio (OTRATIO): greater overtime hours can mean a fatigued crew or be symptomatic of poor management.

21. Disciplinary Procedures in Writing (DISCIP): implies the degree of formality observed in enforcing production standards.

22. Engineering-Based Work Standards (STAND): indicates a sound basis for enforcement of production quotas or administration of incentive systems.

23. Geographic Area (REGION): southern location or other (1 = South); lagging unionization in the South may indicate higher productivity.

24. Hourly Wage Paid to Warehouse Labor (RAWAGIN): union wages typically exceed nonunionized.

25. Hourly Wage Paid Relative to the Going Rate for Warehouse Workers in the Local Labor Market (WRATIONIN): relatively higher wages attract higher quality labor.

Outbound Variables

Variables postulated as related to factors influencing outbound productivity were as follows. The interpretation of these variables is similar to those for the inbound operation.

1. Labor Productivity (OUTCHM): outbound cases per labor hour.
2. Physical Plant Size (FLAREO).
3. Number of Items Carried (ITEMSO).
4. Number of Repack Items Carried (REPACKS).
5. Outbound Operating Hours (OUTHRS).
6. Size of Shipping Dock Facility (SHDOCPCT).
7. Portion of Loading Done by Order Selectors (PCTLOAD): direct loading by selectors increases outbound productivity.
8. Percent of Shipments Unitized (PCTUNIT): a greater degree of unitization reduces handling thus increases labor productivity.
9. Average Order Size (ORDSIZE): larger orders increase the order selection "hit" frequency per linear foot of travel which increases productivity.
10. Inventory Turnover (INVTOO).
11. First Level Supervisory Span of Control (OUTSPAN).
12. Employment Turnover-Warehouse Labor (HRTOO).
13. Employment Turnover-Foremen (SUPTOO).
14. Unionization (UNIONO).
15. Warehouse Ownership (OWNERO).
16. Absentee Rate (ABSTPO).
17. Overtime to Total Hours Ratio (OTRATIO).
18. Disciplinary Procedures in Writing (DISCIPO).
19. Engineering Based Work Standards (OSTAND).
20. Use of Productivity Incentives (INCENT): monetary or other forms of incentives can enhance productivity.
21. Geographic Area (REGIONO). (1 = South).

22. Hourly Wage Paid to Warehouse Labor (RAWAGOUT).

23. Hourly Wage Paid Relative to the Going Rate for Warehouse Workers in Local Labor Market (WRATIOUT).

EMPIRICAL RESULTS

Further estimation was done using the FACTOR subroutine of the SCSS conversational statistical computer program (Nie et al. 1980, pp. 457-510). Principal components factor extraction techniques were used on variables normalized by the Kiser algorithm. Factors are extracted until the eigen value of the correlation matrix associated with a factor no longer exceeds utility and therefore does not explain as much variance as a single observed variable. Principle components extraction was employed rather than iterative maximum likelihood or least squares techniques for two reasons. First, maximum likelihood solutions which use initial communality estimates provide a statistical measure of goodness of fit between the original off-diagonal elements of the correlation matrix and those of the matrix reproduced from the factor loadings. This approach, while preferred to principle component extraction, proved unusable due to convergence problems perhaps resulting from a high degree of cullinearity among the observed variables (Nie et al. 1975, p. 479). Second, the results of the analysis of the inbound function, where a maximum likelihood estimate did converge, were very similar to those based on principal components extraction. Recalling that factor extraction focuses on explaining covariation while principle components analysis focuses on explaining total variation, one can conclude on the basis of similar results that the unique portion of the variability in each observed variable is relatively small. Consequently, principle component factor extraction appears to be appropriate in this application and it was decided to report the results on that basis for both outbound and inbound functions.

Inbound

The inbound analysis combines truck and rail receiving with storing into one inbound function. Initially, when all the variables described above were inserted, five factors were extracted, one more than expected. The factors, however, did not lend themselves to description and several variables had uniform loading across most factors. This situation is commonly used as justification for excluding variables with little explanatory value (Comrey 1973, p. 226). Other factors loaded on variables like facility size and region, which characterized the sample rather than explained it and were dropped. The eight remaining variables loaded on three factors (Table 1).

The first factor relates heavily to a strongly unionized warehouse and is termed "effects of strong unionization." Several of the variables related to characteristics of union-dominated warehouses. Unions for example wish to provide additional work for their members by providing the unloading labor (TRUNLOAD). As a means of maintaining control and order indisciplinary procedures, stronger locals typically require that disciplinary procedures be described in detail in the collective bargaining agreement (DISCIP). Finally, union employees tend to remain longer than nonunion ones (Freeman 1977). Whether this is due to lower voluntary quits or to more difficulty in firing imposed by union grievance procedures cannot be determined from the available data.

The significant aspect of the first factor is, however, the loading on productivity: .66. Not only are strongly unionized warehouses relatively productive, unionization explains over 40 of the variability in physical productivity among the sample warehouses. Thus, at least on the inbound side, unions contribute to rather than detract from productivity. Unionized workers are as expected paid more than nonunionized ones as a wage variable loaded heavily in another iteration of this analysis (not reported).

Table 1: Factor analysis of inbound data in food distribution center productivity*

Variable	Factor 1	Factor 2	Factor 3
UNION	.862	.090	-.174
INCHM	.659	-.500	.223
TRUNLOAD	.628	.276	.228
INSPAN	-.024	.779	.198
HRTO	-.204	-.674	.450
DISCIP	.402	.558	.336
SUPTO	.079	.265	.759
ABSTP	-.040	.065	-.497
Percentage of variance explained in the unrotated solution	27.0	19.0	14.9

*Principal components extraction of nonunitized variables, varimax rotation.

Data Source: Cornell Report on Productivity in Grocery Distribution Centers, 1979 and 1980.

Factor two describes a poorly run warehouse which is not heavily unionized. It is titled, "poorly managed" and is characterized by high employee to first-line supervision levels (INSPAN) and positive although not very large supervisory turnover (SUPTO). Hourly turnover (negative, HRTO) and disciplinary procedures (DISCIP) both load relatively heavily, suggesting perhaps that while the procedures are in place to discharge workers, supervision may be inadequate to implement them. For workers, the relative laxness of the supervisory atmosphere in these warehouses may reduce voluntary terminations.

The third factor we interpreted as another form or technique of management, that is, management removed from the direct coordination of the activities. Consequently it is referred to as "second-line supervision." This factor is dominated by high levels of turnover of both hourly and supervisory personnel. In the absence of a strong union effort these results would be consistent with upper level management putting pressure on employees to produce. The result is the appearance of dedication by employees as measured by low absentee rates but the important strong positive effect on output is missing. Levels of hourly employees relative to first line supervisors are rather low, but the high turnover of supervisors appears to be diminishing supervisory effectiveness.

As interesting as the variables which loaded heavily in Table 1 are, those which did not also warrant attention. The loadings on facility size were small, supporting the belief that there are no important size economies in physical labor productivity in food distribution centers. The weights on the other facility-related variables were also low. This can imply that, while these factors may be important in some operations, the single most important factor explaining interwarehouse productivity differences is management.

From the results it is evident that close supervision is essential to high productivity. Whether this supervision leads to better coordination or better morale or a combination is not known. However, in the absence of good morale, as is apparently the situation with the "second-line supervisor" case, productivity suffers. Apparently the necessary supervision/coordination can be contributed either by firm employees or by a strong union organization. Thus when the costs of union compared to nonunion wages are compared it should be recognized that the unionized work environment is providing an important coordination function as well.

Outbound

The outbound analysis combines selection and shipping functions into one outbound operation. Selection is the most important in the warehouse in terms of manhours as it typically accounts for 35 percent of direct labor hours (Kochersperger 1979, p. 2).

Like the input side, output loaded on three factors, none of which related output to physical characteristics (Table 2). In this instance the importance of high levels of first-line supervision is even clearer. In factor three, relatively high supervisory levels explain 80 percent of the variability of productivity among warehouses in the sample. This result is expected considering the difficulty of supervising order-selector work in many parts of the warehouse and the need to coordinate closely selection activities with those on the shipping dock. Despite this many warehouses allocate supervisors improperly. For the warehouses in the sample the average number of workers per supervisor is 9.7 in truck receiving, but 28.2 in order selection (Cornell Report 1980, pp. 18 and 37). Perhaps one reason for this is the scheduling of selection at night (a less desirable time to work) than during the day when the receiving is done.

Table 2: Factor analysis of outbound data on food distribution center productivity*

Variable	Factor 1	Factor 2	Factor 3
SUPTOO	.815	.129	-.185
INCENT	.749	-.101	.349
OUTSPAN	.747	-.001	-.525
INVTOO	-.216	-.776	.084
UNION	.042	.721	-.179
FLAREO	-.220	.680	.175
OUTCMH	.045	-.205	.902
ABSTPO	-.313	.362	.488
Percentage of variance explained in the unrotated solution	28.4	22.7	15.3

*Principal components extraction of normalized variables, varimax solution.

Data Source: Cornell Report on Productivity in Grocery Distribution Centers.

Comparing this factor with a similar one on the input side, the obvious question arises -- why does unionization load so moderately on the output function? The answer could lie with how the two functions are organized. Output receives substantial management attention both because of its relative importance in terms of total employee hours and the significance of the outbound operation in providing high service levels to the stores. Service levels are typically defined in terms of the number of shipments per week, order-delivery turnaround time and the extent to which store orders are filled. In addition, the delivery truck drivers are generally firm employees so that management controls the entire operation.

Operations at the input side, on the other hand, are considerably more autonomous. Inbound shipments are typically delivered by contract or common carriers who cannot necessarily be compelled to adhere to a schedule established by management. At the same time both the drivers and the warehousemen in unionized warehouses are typically members of the Teamsters Union. The comaraderie and brotherhood which exist among Teamster members as well as among members of other strong unions enhance an informal arrangement and coordination at the receiving dock. Warehouse management for its part is often excluded from this working arrangement, unable or unwilling to control the critical aspects of the operation. As a result the operation of the receiving operation often becomes, defacto, under the control of the union members. Put another way, members of strong unions often have more loyalty for the union than for their employer and they can be expected to operate in ways reflecting this allegiance.

When absolute pay levels were included among the variables in an analysis not presented here, unionization was again, as expected, associated with higher wages. Relative wage rates of the sample firms compared to

warehousemen in neighboring SMSAs showed little effect on either labor turnover or directly on productivity. Relative wage levels were, however, strongly associated with turnover among supervisors. This result makes sense if upper management practices wage compression -- the close pegging of supervisors wages to those of hourly employees. Data are not available to measure this assertion directly, but it is generally recognized as existing in the warehousing sector. If true, wage compression is further evidence of the underrating of first-line supervision by upper level management. Gerald Peck, President of the North American Wholesale Grocers Association (NAWGA), however, notes a recent change in attitudes among employers which is reflected in an increased interest in training first-line supervisors (Modern Materials Handling 1980, p. 113).

While factor three describes the importance of supervision for outbound productivity, factor one relates to the substitution between supervisors and incentives. Consequently it is titled, "supervisor/incentives substitution." Incentives have been found to substitute for direct supervision by allowing hourly workers to work in areas where they are often hidden from sight. Incentives are viable only in instances where accurate labor standards exist. Only a small percentage of distribution centers are using incentives and in 1979 only 15 percent of responding warehouses had any standards for warehousing activities (Modern Materials Handling 1980 pp. 62 and 67). There has, nevertheless, been a notable increase in the use of incentives in grocery warehousing in recent years perhaps signaling a trend in this area (Cornell Report 1979, p. 29 and 1980, p. 36). While some labor contracts prohibit direct monetary incentives, the awarding of goods like color television sets or time off for exceeding standards can be substituted.

The heavy positive loading on supervisory turnover in the first factor could reflect a cause or an effect. The institution of incentives could

lead to the laying off of supervisors as superfluous. Considering the difficulty of locating a good supervisor this seem unlikely. More plausible is the substitution of incentives for supervisors in operations which have difficulty retaining qualified supervisors.

The second factor relates to warehouse efficiency, but not to physical labor productivity. The negative relationship between inventory turns (INVTOO) and warehouse size (FLAREO) describes larger warehouses as carrying relative greater inventories compared with smaller ones. This factor is titled "inventory efficiency," and, while it lies outside the principal scope of this paper, it is nonetheless significant for overall warehouse efficiency. The interpretation of this result is not clear from the available data. On the one hand the inventories may result from speculative purchases of products with anticipated price increases. On the other, they may be due to careless buying which proceeds until the physical capacity of the warehouse is reached, necessitating more careful planning. Based on our experience with the industry we feel careless buying is a more likely explanation than the other. If this is indeed correct then the excessive inventory costs for larger warehouses is substantial especially during the current period of record interest rates.

The high loading on the union variable in this factor is more a trait of the sample than illustrative of a causal relationship. The sample is characterized by a group of larger warehouses located in the Northeast, a heavily union dominated area. Thus the loading on unions simply characterizes the sample.

SUMMARY AND CONCLUSIONS

The purpose of this paper is the identification of the significant factors which explain the large differences in physical productivity among dry grocery distribution centers. Several different sources relying on

distinct samples and estimation procedures have reported interwarehouse productivity differences in the neighborhood of 10 to 40 percent (Cornell Report; Grinnell; Wolff).

Identifying factors associated with labor productivity is important at this time when productivity in food distribution is generally lagging, pushing retail prices up. Without significant productivity improvements, food distribution center costs, estimated currently at 2.5 percent of the retail price of food (Kaylin 1968, p. 13), will climb further.

Previous writers on warehouse productivity have identified three broad areas as influencing the operating efficiency of individual operations, (1) such physical and operational characteristics as facility size, selection methods, etc., (2) employee motivation and coordination encompassing supervisory levels and wages, and (3) unionization. Despite general agreement on the contributing factors there is considerable latitude on how and to what degree individual variables affect productivity. The issue is thus an empirical one.

Previous efforts to examine the affects of individual variables through production function analysis have been largely unrewarding. While general data limitations contributed to this result, the difficulty of quantifying differences in management within the rigid specification requirements of a production function likely make this approach inadequate. As an alternative, this study employed factor analysis. Factor analysis has the advantage of providing a classification of types of warehouses based on a grouping of certain characteristics. Its principal disadvantages are that no quantification of the relative importance of individual characteristics is possible and the causal nature of the proposed model is more open to debate. The results from this study should be considered preliminary and used as a basis

for further analysis, whether done by management at the firm level or by using other empirical tools at the sector level. For the analysis, data reported in the 1979 and 1980 issues of the Cornell Report on Productivity in Grocery Distribution Centers was used. The sample is nonrandom, representing more heavily chain as opposed to wholesaler owned operations. For this reason, too, the results presented here should be considered preliminary.

The empirical results support the expectation that different management techniques are most important in explaining productivity variations. Management style was important for both the input and output functions but in slightly different ways. On the inbound side productivity could be achieved by either close supervision or by laxer supervision in a strong union environment. Unionized warehouses had higher wage rates than nonunionized ones, but the positive relationship between unions and productivity was different than that expected by many observers. A third management style which we interpret as pressure to produce from upper level management was shown to be inadequate. On the output side unions were less significant in the way the functions were coordinated, probably because of the greater emphasis management place on this operation. A strong relationship was shown between productivity and smaller numbers of employees per foreman, or its substitute, productivity incentives.

Physical factors were found to be far less important than management structures in explaining productivity differences. Apparently the motivation levels and effective coordination of employees was determined by the general interpersonal relationships in the warehouse and not by the physical constraints. Warehouse size, however, was found to be an important factor in explaining inventory turns. Since greater turns imply lower inventory levels and hence lower costs, the results suggested larger warehouses with more stock space may have less effective inventory control procedures. An

alternative interpretation which we do not favor is that the higher inventory levels result from speculative buying.

The results from this study may be used by warehouse managers and their representatives for evaluating their operations. Academic groups may view these results as hypotheses for subsequent evaluation, and those interested particularly in the effects of unionization on productivity may find that the factor analysis approach offers insights not available through case studies or cross-sectional analysis at a more aggregate level.

The preliminary nature of the investigation reported here certainly leaves unfulfilled the need for theoretically rigorous yet practical economic research in the area of food warehousing. Yet, results of classical production and cost function analyses have been inadequate. A potentially fruitful direction for the future research might involve the use of classical production or cost function framework within which to measure warehouse efficiency using more (statistically) rigorous econometric tools. Once quantified, relative efficiencies can be explained in terms of a few important factors extracted from data on warehouse operations and management practices. Factor analysis can assist in identifying the important traits and in computing factor scores using measurable variables. By formulating and testing models with efficiency as the criterion variable and important factors as the hypothesized casual variables researchers should gain a better understanding of what influences productivity and by how much.

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