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ITJ

ISSN 1812-5638

# INFORMATION TECHNOLOGY JOURNAL

ANSInet

Asian Network for Scientific Information

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (24): 8308-8312, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.8308.8312


# What Makes a Difference? An Evaluation and Identification Approach to Distribution Center Productivity Using DEA

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**Abstract:** This research proposes an evaluation and identification approach illustrated in the context of 108 Distribution Centers (DCs) of a big soft drink company. We measure DC productivity, find the relationship between different impact variables, evaluate and identify what are the most influence variables using Data Envelopment Analysis (DEA) methodology with over 2 years' weekly data. The results showed high productivity cannot usually guarantee good revenue performance. if distribution center want to promote their productivity, they can reduce their forecast error, improve the fill rate but all hardworking may not be able to boost sales.

**Key words:** Productivity, distribution center, data envelopment analysis, hypothesis test

## INTRODUCTION

The benefits of high productivity are everywhere. Productivity is the most important variable in governing economic production activities (Alby, 1994). From a view of macroeconomic side, productivity growth raises the quality of life because more income improves people's ability to consume, enjoy entertainment and improve housing and education. Productivity growth also sets attach importance to increase firm performance (Palia and Lichtenberg, 1999). Distribution operations in many companies are facing enormous pressure. With a sluggish economy and brutal price competition, most logistics organizations are being asked to achieve year-over-year cost reductions on an annual basis. Zosel (2009) Pepsi Co., for example, has a multi-year productivity program expected to generate $1.5 billion of incremental cost savings by 2014 through optimization of operating practices and organization structure, including a reduction in force of about 8,700 employees, about 3% of global workforce (Pepsi Co, 2012).

An extensive body of literature has measured the productivity performance. A pertinent discussion of the advantages and disadvantages of five common ratios employed to measure productivity: Single Factor Productivity, Multifactor Productivity, Total Productivity, Managerial Control Ratio and Productivity Costing have been provided (Hawaleshka and Mohamed, 1987). The PPP and the APC models can be found which have different ways of deflating price changes (Belcher, 1985; Miller, 1984). Total productivity is said to be a "ratio" of all measurable output to the sum of the measurable inputs (Edosomwan, 1995).

A key contribution of our research is to consider the actual operational situation and establish a standard productivity conceptual model to measure the Distribution Center (DC) productivity performance. "Ratio", outputs and inputs are not sufficient to explain and make a comparison among 108 DCs. Most firms do have adequate productivity measurement procedures at the DC operational level (Belcher, 1985; Alby, 1994).

DEA constructs the best performance "frontier" and reveals the relative efficient Decision-making Units (DMUs) observations in input/output space (Charnes *et al*., 1978; Banker *et al*., 1989). We examine and evaluate the DC productivity performance using Data Envelopment Analysis (DEA).We focus on benchmarking in the supply chain management area. We measure DC productivity, find the relationship between different impact variables, evaluate and identify what are the most influence variables using Data Envelopment Analysis (DEA) methodology with over 2 years' weekly data.

This study proceeds as follows. In Section 2, we provide a review of the and. The research methodology is developed in Section 3. The Section 4 reports the main statistical results and a discussion of the results and conclusion.

## LITERATURE REVIEW

**Productivity performance:** Productivity performance closely connected to the use and availability of resources. If a company's resources are not properly used, we can say the productivity performance is not well or reduced. There is becoming increasingly important in distribution channel management that how to involve the reduction of

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order cost to facilitate deliveries of goods from the manufacturer to the retailer (Donga *et al*., 2007).

Productivity performance also created the value for a company. Thus, High productivity performance means more production, save time, lower cost and optimized management and operational process at the same time. With regard to firm performance, a firm like CVS pharmacy has managed to reduce its backroom inventory to 10-15 percent of total inventory through ER (Chain Store Age, 2001). Furthermore, in a survey of business executives, Myers *et al*. (2000) found that the use of automatic replenishment service programs was positively related to firm performance. Efficient replenishment and improve productivity performance is necessary for the firm (Donga *et al*., 2007).

**Inputs and outputs considered in DC operations and management:** In this study, productivity performance is related to the inputs and outputs of a distribution center. Operations and management processes and facilities can impact the result (Ahire and Dreyfus, 2000). Frazelle (2002) measured the performance with five interdependent logistics processes, such as Customer Response (CR), Inventory Planning and Management (IP and M), supply, Transportation and Distribution (T and D) and warehousing and DC operations (DCO).

Ross and Droge (2004) and Edward developed input-output models of warehouse systems to assess operational efficiency. Edward considered all of the critical resources as inputs (labor, space, storage and handling equipment) and the different workload requirements as outputs (broken case, full case and pallet picking, storage and order accumulation). Ross and Droge (2004) found that resource inputs can include any combination of labor (e.g., workforce size, experience, man-hours required or dollar cost), vehicles (e.g., fleet size or capacity), equipment (e.g., size or capacity, machine availability), capital (e.g., net present value) and/or information (e.g., demand requirements). The input variables available for this research are fleet size, driver experience and delivery route index. However, commodities delivery is the only output. Our research not only considered what they mentioned but also concerned inputs like the information system (e.g., WMS) and outputs like order error and sales performance.

**DC productivity measures:** Numerous studies have measured the productivity performance. As a result, productivity was presented in three forms (Edosomwan, 1995):

- **Partial productivity:** the ratio of the total output to one class of inputs
- **Total factor productivity:** the ratio of total output to sum of associated labor and capital (factor) inputs
- **Total productivity:** the ratio of total output to all input factors

Tongzon (1995) conducts a short-term analysis of terminal efficiency. He found a significant correlation between throughput and terminal efficiency as the latter is defined as "average number of containers per berth hour''. Others have observed this relationship between output and efficiency, including Caves and Christensen (1988) and De Neufville and Tsunokawa (1981).

The parametric approach develops a causal relationship between input and output measures. Appropriate weights are used to transform individual inputs and outputs into a common unit. As a result of difficulties with the parametric approach, many researchers resort to an alternative approach for assessing productivity; i.e., non-parametric. A methodology is presented for measuring productivity, Data Envelopment Analysis (DEA), which has been the most widely used non-parametric approach in productivity studies (Pels *et al*., 2001, 2003; Yoshida and Fujimoto, 2004).

## RESEARCH METHODS

**Data envelopment analysis:** According to Tavares (2002) who conducted a comprehensive bibliography of Data Envelopment Analysis (DEA), the number of DEA publications between 1978 and 2001 has exceed 3200 publications; these included research papers, event papers and books covering a wide range of applications and industries, however, among the 3200 publications, only several articles concerning warehousing are found.
Talluri and Baker (1996, 2002) proposed a two-phase mathematical programming model for effectively designing value chains (a combination of independent business processes such as suppliers, design, manufacturing and distribution processes) where extensions in data envelopment analysis and integer programming were utilized in the solution procedure. In phase 1 they used data envelopment analysis to distinguish the performers and in phase 2 a binary (0-1) goal programming model was used for selecting an effective combination of good performers. Their model also provides effective benchmarks for improving poor performers in every category of the supply chain processes.

In another study (Talluri and Yoon, 2000) applied DEA for the evaluation and selection on Advanced Manufacturing Technology (ATM); they used cone-ratio as a special case of the Assurance Regions concept, which was introduced by (Thompson *et al*., 1986) as an extension to DEA. Their study utilized a combination of a Cone-ratio Data Envelopment Analysis (CRDEA) and new methodological extensions in data envelopment analysis to assist them in the evaluation and selection of robots used in manufacturing. (Hackman *et al.*, 2001) developed an input-output model of a warehouse system to assess the operational efficiency using Data Envelopment Analysis (DEA).

Distribution center productivity using the DEA model The data used in this research were collected for similar DCs operated by a soft drink company that operates over 108 DCs in the US. The selected DCs have common processes, similar product of consumer electronics and telecommunication equipment and similar inputs and outputs.

Figure 1 provides the general framework for this research. We assumed that "COGS", "Delivery returns", "PV", "Inventory stock", "Forecast Demand" and "Over Forecast Error" as the inputs, "Revenue", "Fill Rate", "Customer Coverage" as the outputs. The description of the inputs and outputs variable name is on the Table 1.

The final model to be estimated is:

$$\begin{aligned} DEA_{it} &= b_1 COGS_{it} + b_2 \text{Delivery returns}_{it} + b_3 PV_{it} \\ &+ b_4 \text{Inventory stock}_{it} + b_5 \text{Forecast Demand}_{it} \\ &+ b_6 \text{OverForecast Error}_{it} + b_7 \text{Revenue}_{it} \\ &+ b_8 \text{Fill Rate}_{it} + b_9 \text{Customer Coverage}_{it} \end{aligned}$$

where, i designates d istribution center, t designates time.

## DEA RESULTS AND CONCLUSION

We can see the DEA productivity results in Table 2. It showed 1118 DEA productivity contained 108 Distribution Centers in the US. There is an obvious gap between Minimum and Maximum Productivity, revenue and overcast error.

We described the DEA Productivity, revenue, overcast error and fill rate performance trend. Figure 2 showed us the different broken line with the same Distribution Center during Feb. 2009 to Jan. 2011. If we

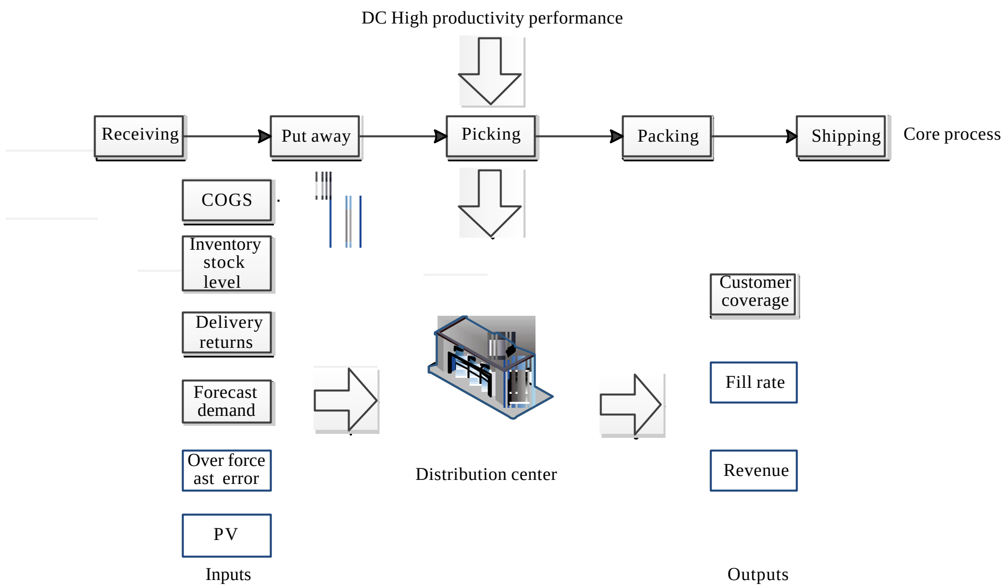


Fig. 1: Framework for 108 DCs productivity analysis

Table 1: Variable names and definitions

| Variable name | Description |
|---|---|
| Customer $coverage_{it}$ | The number of retailers (customers of the distributor) served by distribution center i in period t |
| Product $variety_{it}$ | The number of stock keeping units (SKUs) sold at distribution center i in period t. |
| Over forecast $error_{it}$ | The ratio of difference between forecast demand and actual order amount received by distribution center i in period t to the actual order amount |
| Inventory stock $level_{it}$ (in 10,000 cases) | The average inventory level in distribution center i at period t |
| Fill $rate_{it}$ | The percentage of product cases filled in the total cases ordered at distribution center i in period t |
| Delivery $returns_{it}$ | The amount of products returned to distribution center i at period t |
| Forecast $demand_{it}$ (in 10,000 cases) | Forecast demand for distribution center i in period t |
| $COGS_{it}$ | Cost of goods sold in distribution center i in period t |
| $Revenue_{it}$ | Revenue in distribution center i in period t |

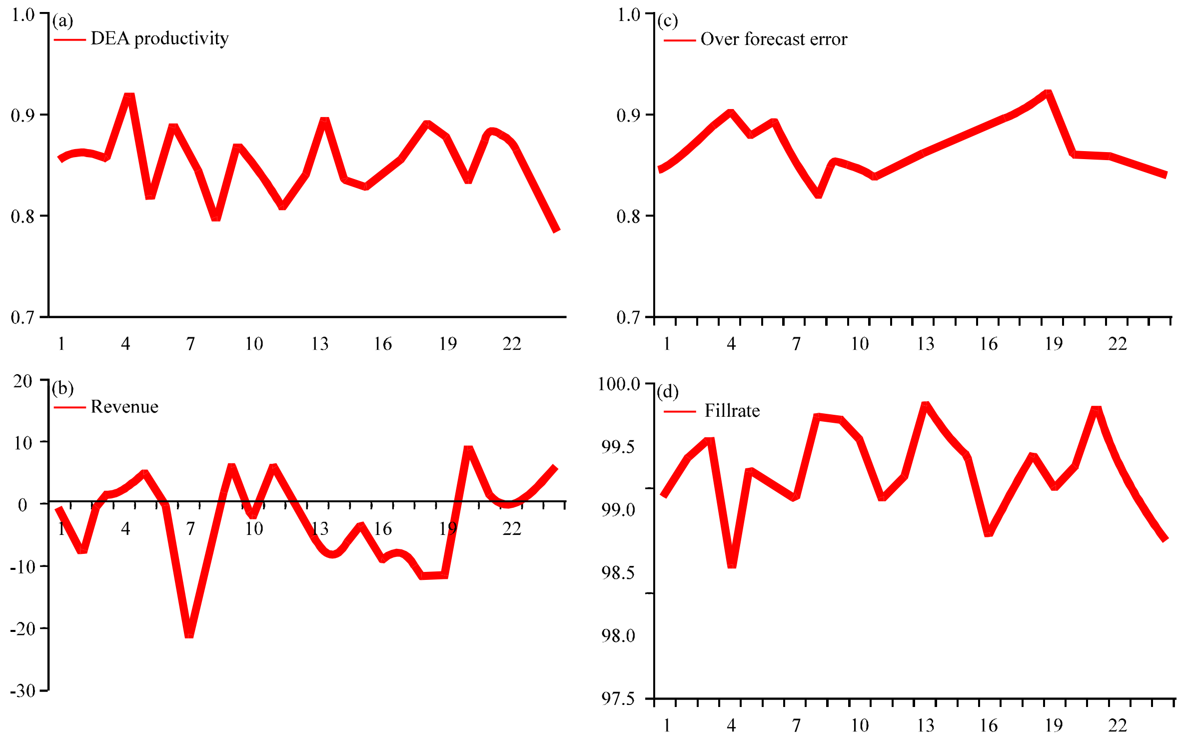


Fig. 2: One of the 108DCs Productivity, revenue, overcast error and fill rate performance during Feb. 2009 to Jan. 2011

Table 2: DEA productivity, revenue, overcast error and fill rate performance results

| | N | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| DEA productivity | 1118 | 0.75172387 | 1 | 0.937231 | 0.056116 |
| overcast error | 1118 | -47.96310 | 9.98756 | -2.5761185 | 7.62266247 |
| Revenue | 1118 | 9754 | 9945025 | 2554930.16 | 1909660.150 |
| Fill rate | 1118 | 94.9677 | 100 | 99.206783 | 0.6142553 |

ignore the revenue broken line, more of us may guess a conclusion that high productivity results high revenue performance. However, the truth is when the productivity goes down, the revenue amazingly goes up sometimes. It isn't the real negative correlation. We can also found the overcast error is negative correlation with the productivity. It means a distribution center did a good forecast demand, they can be measured high productivity. Fill rate is uncommon to found in the previous research. The trend showed us it is the positive correlation with the productivity. Further to think about the relation between revenue and fill rate is not relative. Above all, if distribution center want to promote their productivity, they can reduce their forecast error, improve the fill rate but all hardworking may not be able to boost sales.

## ACKNOWLEDGMENT

The authors would like to thank for the support by PHD Innovation Foundation of Beijing Jiaotong University under the Grant KBJB13022536.

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