Inventory management: Is there a knock-on effect?

Gyula Vastag\textsuperscript{a,*}, D. Clay Whybark\textsuperscript{b}

\textsuperscript{a}Kelley School of Business, Indiana University, 801 West Michigan Street, BS 4027, Indianapolis, IN 46202-5151, USA
\textsuperscript{b}Kenan-Flagler School, University of North Carolina, Chapel Hill, NC 27599-3490, USA

Abstract

Over the last several years a number of independent empirical studies have shown that organizational performance is related to a portfolio of management techniques, clearly demonstrating that there is no single “silver bullet.” In fact, these studies indicate that performance is positively correlated with the number of techniques employed and the depth of their implementation. Operational outcomes in areas like product quality, on-time delivery and productivity, as well as market measures like margins and export sales are both positively related to the implementation of a variety of techniques. This paper explores the relationship between the use of effective inventory management practices (as reflected in inventory turnover) and the implementation of other manufacturing practices. The hypothesis is that effective inventory management practices have a positive knock-on effect on the implementation of other practices. Since organizational performance is related to the implementation of multiple practices, the knock-on effect should have a positive effect on performance as well. The results show that inventory turnover is significantly related to the implementation of other techniques and weakly related to an index of overall company performance. This suggests a positive knock-on effect, but that it takes more than inventory management to achieve high levels of performance. Having established the knock-on relationship adds more evidence to the notion that management excellence in one area begets management excellence in others.

\( \textsuperscript{c} \) 2004 Elsevier B.V. All rights reserved.

Keywords: Manufacturing and inventory practices; Competitive advantage; Large-scale survey research

1. Introduction

Over the last several years, a number of international groups have independently collected and analyzed empirical data on manufacturing practices. For example, the Boston Roundtable (Manufacturing Futures Project) has been gathering data on manufacturing strategy practices in the United States, Western Europe and Japan since 1981 and more recently has initiated projects in other developed countries (see, for example, De Meyer et al., 1989; Kim and Miller, 1992; Roth and Miller, 1992). Professor Chris Voss of the London Business School has spearheaded a
project that relates practices to performance in number of (primarily European) countries (Voss et al., 1995). Many of the results of the studies appear under the rubric “Made in...” (Collins, 1995). Professor Roger Schroeder of the University of Minnesota leads a group using survey data from the United States and other developed countries to determine which practices are associated with world-class manufacturing (Schroeder et al., 1996; Flynn et al., 1997; Flynn et al., 1999). The Global Manufacturing Group has surveyed firms in developed and underdeveloped countries around the world on their manufacturing practices and performance (Whybark and Vastag, 1993).

A number of these studies have independently shown a significant positive correlation between the number and intensity of manufacturing practices in use and the performance of a firm. Other work has found the same relationship for specific practices and/or specific performance measures. For example, Winch and Swamidass (1999) studied the relationship between technology and performance in the United Kingdom. Using Global Manufacturing Research Group (GMRG) data, Boone and Whybark (1995) and Corbett and Whybark (1996) developed evidence for the relationship in studies of asset productivity and quality programs. Adam et al. (1994) studied practices for improving quality. In addition to supporting the positive correlation between the number and intensity of manufacturing practices that a firm has in place and the operational and market performance that it achieves, it is remarkable how many of these groups have independently depicted the relationship as a “football.”

To develop the football, indices of manufacturing practice implementation and performance are first created (Fig. 1). They are formed by converting the relevant questions on the survey to Likert scales, summing the responses, and calculating the sum as a percentage of the maximum possible score. A typical question concerning manufacturing practices might be, “To what extent has statistical quality control been implemented in your organization?” The responses could range from 1 (not at all) to 5 (throughout). Thus, higher numbers on the manufacturing practices index mean that more practices are in place and/or they are more extensively used. Performance questions might involve comparisons with the competition or absolute measures. Comparisons with the competition can range from 1 (much worse) to 5 (far better) while absolute measures (e.g., work in process reject rates) can be converted by assigning the best 20% a “5” and the worst 20% a “1.” The higher the sum of the responses, the better the firm is doing competitively and/or on operational performance.

The conclusion seems to be, “the more, the better.” But several researchers have argued the choice of practices is important in order to have the appropriate “portfolio” in place (De Meyer, 1990). Others have argued that the order of implementation is important and some evidence exists that starting with quality efforts and moving to others is a good idea, a notion that has been termed “the sandcone model” (Ferdows and De Meyer, 1990). However, a study (Ahmed et al., 1996) suggested that the marginal returns to implementing additional strategy practices are diminishing. This might be represented by a firm moving along the upper edge of the football as practices are added, for example. Though the specific findings vary from study to study, the general shape of the football holds across a wide variety of industries, companies, countries, economies and research questions.
This paper uses the GMRG’s second-round database to deepen our understanding of these relationships and to explore the role of inventory management in the phenomena. The questionnaire contains measures of operating performance and managers’ assessments of the firms’ relative competitive position in the industry. We first demonstrate that the relationship between practices and performance holds for this data. We then determine if there is any “knock-on” effect by exploring the relationship between inventory turnover and other manufacturing practices in the company. Finally, we relate inventory turnover to company performance.

2. Developing the football

In this section, we develop the data and plot the performance index against the practice index. The nature of the sample data and development of the indices are described before drawing the football.

2.1. Sample data

The sample was compiled from surveys of manufacturing firms in several countries and industries (although the two primary industries are non-fashion textile and small machine tool). The survey was a random sample of firms in a given geographical area (whole countries in some cases and regions in countries like the United States) and was administered to a senior manufacturing executive or general manager. The composition of the sample is provided in Table 1.

The firms that were surveyed are in countries all over the world: from Asia to Europe and South to North America. They include both centrally planned and market economies. In addition, the industries surveyed provide a variety of different processes: from batch-oriented to process-oriented and disparate levels and types of capital investment. Earlier GMRG studies have indicated that there are manufacturing practice differences between the industries and even greater ones between countries. Thus the sample provides a broad cross-section of manufacturing in the world. We will use the entire data set for this study. This is consistent with previous research on the practice and performance indices.

2.2. The indices

The manufacturing and performance indices were constructed from opinion and descriptive measures from the questionnaire. Because the GMRG survey was designed for very general purposes, it does not have as large a number of practice and performance questions as some of the research that was used to demonstrate the football. There were, however, 23 items available for the practice index and 23 for the performance index. The items for each index are indicated in Table 2.
2.3. Scoring the responses

The opinion data were gathered using 5-point Likert scales. The resource investments for the practice index were anchored with “not at all” to “to a great extent.” The competition comparisons for the performance index were anchored with “far worse” to “much better.” On the other hand, the descriptive measures were filled in directly (e.g. scrap rate) or were derived from other data (e.g. sales per employee). The distributions of many of these objective values were skewed. Rather than eliminate firms with extreme points or use something like a logarithmic transformation, the objective values were converted by assigning the lowest 20% (bottom two deciles) of the firms a “1” and the highest 20% (top two deciles) a “5”. This had the advantage of keeping the data, but not weighting any extreme points too heavily. This approach is similar to that of Filippini et al. (1995) though they split their data into quartiles rather than quintiles.

2.4. Constructing the indices

Before constructing the final practice and performance indices, firms that had responses for fewer than half of the individual questions for either index were eliminated from the sample. We
summed the scores for each response for the completed questions for each index for the remaining firms \((n = 1160)\). The total score thus calculated was compared to the maximum possible score for each index of 115 \((23 \times 5)\). The percentage of the maximum possible score is used as the index. For example, a firm whose total score on the 23 practice questions was 69 would have an index value of 60 \((69/115)\). This results in indices that, theoretically, can range from 0 to 100 (actually from 25 to 95).

To develop the “football” for the GMRG data, the full 23-variable indices were used. The resulting plot of the performance index against the practice index is shown in Fig. 2. There is considerable scatter in the data, more than in the footballs for some of the other research. Possible explanations for this could include the number of variables, the objectives of the surveys, the countries included in the sample and the industries evaluated.

Despite the scatter, however, there is a general tendency for firms with higher practice scores to have higher performance scores. A simple linear regression confirms this. The results show a highly significant correlation between the two indices. Although only around 10% of the variance is explained by the results, there is a positive relationship between the practice and performance indices. The regression results are shown in Table 3. It is consistent with other research. The sample size is 1160 (as opposed to 1222) since some of the firms did not report all the data needed to construct both the indices.

3. Inventory turnover and manufacturing practices

In this section, we look at the relationship between the manufacturing practice index and

Table 3
Regression analysis for the practice and performance indices

<table>
<thead>
<tr>
<th>Sample size</th>
<th>( R^2 )</th>
<th>Significance</th>
<th>Coefficient</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1160</td>
<td>0.101</td>
<td>&lt;0.0001</td>
<td>0.244</td>
<td>50.57</td>
</tr>
</tbody>
</table>

Fig. 2. The GMRG results.
Inventory turnover. Inventory turnover will serve as our proxy for the successful implementation of inventory management practices. We are interested in whether there is a knock-on effect between inventory management practices and the other practices. A significant positive relationship between the two would indicate a possible knock-on effect.

3.1. Inventory turnover

Inventory turnover is most commonly used as a measure of performance. Work on cellular manufacturing has been shown to enhance inventory turnover (Hyer and Brown, 1999). Demeter (2003), in her work on manufacturing strategy, uses inventory turnover as measure of company level competitiveness. Inventory turnover has been used as an “accounting measure of performance” in research on the use of JIT (Huson and Nanda, 1995), a measure of effectiveness for computer systems in China (Hong et al., 1994), for monitoring an inventory control system (Watts et al., 1994), an outcome of employee involvement (Corbett and Harrison, 1992–1993), and as a performance measure for a multi-product manufacturing system (Gunasekaran et al., 1992).

Using inventory turnover as a measure of management effectiveness, as we do here, turns the relationship around. If the inventory turnover is good, it implies that the management practices in place are effective. Moreover, this use of inventory turnover is not without precedent in other research. For example in a study of customer service by Zeng et al. (1999) inventory turnover is used in evaluating management effectiveness. In another instance, Schonberger (2003) argues strongly for inventory turnover as an “indication of effort” in evaluating the performance of companies. Since we are interested in inventory management’s relationship to practices and performance, the use of inventory turnover as a proxy seems to be quite appropriate.

3.2. Preparing the data

Although the practice and performance indices were not intended as measurement scales, a Cronbach’s alpha was run for each. The practice index had a respectable alpha value of 0.79 with all the variables included, so it was left intact for the remaining analysis.

Inventory turnover was calculated as total sales divided by total inventory. Total sales included both export and domestic sales. The inventory total was the sum of the raw material, work in process and finished goods inventories. Any firms that did not report both sales variables and all three inventory variables were eliminated from the sample. The remaining sample size was 951.

3.3. Evaluating the relationship

To test the relationship between the performance index and the inventory turnover a simple linear regression was used. When all 951 data points were included, the results were not significant at all. After a close inspection of the detail data we found one firm (a Spanish machine tool company) that had an inventory turnover value of nearly 1 million. This is about 2500 times a daily inventory turnover, so that point was eliminated. When the regression was run for the remaining 950 firms, the result was significant and the coefficient was positive. In a final run, the inventory turnover range was restricted to greater than or equal to once a year and less than or equal to once a day (that corresponds to values of 1.0 and 365.0). For those firms the results are even more significant. A summary of the results is provided in Table 4.

This analysis makes it clear that there is a relationship between the management of inventory (inventory turnover) and the overall implementation of manufacturing practices. It is not clear whether it is a knock-on or follow-on effect, however. The scatter plot in Fig. 3 does provide some insight into the question. The line through the data uses LOESS to help detail relationships. LOESS is a locally weighted smoothing approach reported by Cleveland (1979).

The line shows that the practice index increases for changes in the inventory turns from very low values, then dips as other practices are added and then increases with the overall index. This implies that inventory management may be important early on, playing a knock-on role and later a
follow-on role. The football would indicate that a portfolio of practices is needed to attain the high performance levels of the best firms. An evaluation of the inventory turnover and performance may help to shed light on the composition of the portfolio.

4. Inventory turnover and performance

In this section, we look at the relationship between inventory management practices and company performance. Again, inventory turnover will serve as our proxy for the implementation of inventory management practices.

4.1. Preparing the data

The Cronbach’s Alpha for the performance index is only 0.55 when all 23 questions are used. When the nine variables that contribute the least are dropped, the Alpha is raised to 0.72. The variables that were dropped are indicated in Table 2. Note that inventory turnover is not included in the revised 14-variable performance index. Therefore, the revised performance index was used for evaluating the role of inventory management practices in performance. Some firms did not report all the data necessary to compute the performance index, so they were eliminated from the sample. The final result is a total of 938 firms in the remaining sample.

4.2. Evaluating the relationship

The first step in the analysis was to test the relationship between the inventory turnover and the overall performance of the firm. A simple linear regression was used for this purpose and it was only marginally significant. After removing the Spanish firm that was an outlier, the regression was no longer even marginally significant. Finally, when the inventory turnover range was restricted to be between 1.0 and 365.0, the regression was still not significant. A summary of the results is presented in Table 5.

It is clear from this analysis that there is not an overall significant relationship between performance and inventory turnover. This is consistent with other findings in the literature. Demeter (2003), for example, finds that return on sales is

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sample size</th>
<th>$R^2$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All firms</td>
<td>951</td>
<td>0.0000009</td>
<td>0.925161</td>
</tr>
<tr>
<td>Deleted the “outlier” firm</td>
<td>950</td>
<td>0.0040450</td>
<td>0.050040</td>
</tr>
<tr>
<td>Restricted inventory turnover to 1.0–365.0</td>
<td>889</td>
<td>0.011958</td>
<td>0.001092</td>
</tr>
</tbody>
</table>

Table 4
Regression analysis for inventory turnover and the practices index

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sample size</th>
<th>$R^2$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>All firms</td>
<td>938</td>
<td>0.0022482</td>
<td>0.146762</td>
</tr>
<tr>
<td>Deleted the “outlier” firm</td>
<td>937</td>
<td>0.0001642</td>
<td>0.695294</td>
</tr>
<tr>
<td>Restricted inventory turnover to 1.0–365.0</td>
<td>877</td>
<td>0.0005690</td>
<td>0.480448</td>
</tr>
</tbody>
</table>

Table 5
Regression analysis for inventory turnover and the performance index
positively related to manufacturing strategy but inventory turnover is unaffected. Tunc and Gupta (1993) found that inventory turnover did not affect total sales. Thus, effective management of inventories is not enough to achieve high levels of performance. Fortunately, the apparent knock-on effect can bring other manufacturing practices into play that work in concert with inventory management to provide high levels of performance. Some evidences for this are seen in Fig. 4, again based on the LOESS smoothing function.

The smoothed line in Fig. 4 is fairly flat but maybe declining for the low values of inventory turnover. For the higher levels, however, there is improving performance with increased turnover. This provides some evidence that as inventory management improves and other practices are added as a part of the knock-on effect, performance improves. It does appear that evaluating inventory turnover for different levels of performance would be worthwhile. That is the analysis reported next.

5. Inventory turnover and the sandcone model

A number of researchers have studied the cumulative capability model testing the theory that high-performance firms continually develop new and improved capabilities. This view is supported by the football from the point of view that more practices are in place for the high-performance firms. Using the data from the Manufacturing Futures Survey Professor Nakane (1986) triggered the development of the “sandcone” model by suggesting that Japanese manufacturers, who sought to offer flexibility, must sequentially address quality, dependability, and then cost improvement with each of these being a precondition to the next capability. Ferdows and De Meyer (1990) made two key changes to this model. Firstly, they suggested the order of capability development is quality, dependability, speed (of product development) and cost efficiency, and secondly, they believed that progress on the development of each capability should never cease.

These researchers would argue that well-honed quality practices provide the foundation upon which the remaining competencies can be built. Using the GMRG database to explore the sandcone theory, Corbett and Whybark (2001) found some evidence of the quality foundation for building competencies. Their approach was to analyze the firms having a practice index around the average. They separated the performance of these firms into three groups: high, medium and low performers. They then compared the composition of the practices for the high- and low-performance groups to see if quality practices were more prevalent in the high-performance group.

We will use the same approach to see if the inventory management practices are more prevalent in the high-performance groups. Another way of looking at this approach is to think about the differences between the firms at the “top” of the football compared to those at the “bottom.” In some sense the firms at the top are realizing a higher performance return on their investment in practices than those firms at the bottom of the football.

To select the firms, we look at the part of the football where the performance differences are the greatest for a given level of practices. This occurs around a practice index of 55 (see Fig. 2). A band of ±5 around this practice index would encompass
firms with performance indices from 38 to 93. A total of 289 firms lie within this band. These firms were divided into three groups. One group of 102 firms was made up of those with the highest performance indices and another group of 100 was comprised of the firms with the lowest. These were called the high- and low-performance groups, respectively. The middle group was not analyzed. There is no difference in inventory turnover for the two groups.

A similar analysis was performed for a band of ±10 around a practice index of 55. This encompassed a total of 533 firms. This provided a high-performance group of 180 firms and a low-performance group of 169 firms. Again the middle group was not analyzed and there was no difference in inventory turnover between the two groups. The results of this analysis are summarized in Table 6.

This analysis suggests again that inventory management alone is not the key to higher performance. There must be other practices in place as well. This is certainly consistent with the basic relationship between practices and performance; the football. From those who have studied the sandcone theory, there is some evidence that quality practices must be among those first involved in the effort to achieve high-performance levels. Effective management of inventory must be there as well, but in combination with other practices.

6. Conclusions

This study has shown that there is a positive relationship between inventory turnover and an index of the use of multiple manufacturing practices. Insofar as inventory turnover is an appropriate proxy for effective inventory management practices, it suggests that there is a knock-on effect. That is, implementing good inventory management practices is associated with the implementation of other management practices. Good effort in one area begets good effort in other areas.

When the inventory turnover data is compared to performance, the differences diminish. There is only a slight positive relationship between improved inventory turnover and improved overall performance. When firms that have nearly the same practice index are evaluated, there is no difference in inventory turnover between the high and low performing firms. This seems to indicate that inventory management does not play the role that quality management does in anchoring the cumulative capability buildup in high performing firms.

There is still a great deal of variance in the data that has been used here. This suggests an obvious need to learn more about country, industry and other classification variables that may help account for the differences. This is especially important since it is clear that some managers are able to extract greater performance from a given set of practices than other managers can. Finding out why should be a high research priority. This means continuing to try to find out if there is a preferred order for implementing practices in a manufacturing company to most effectively improve company performance.

References


