ZERO INVENTORY AND FIRM PERFORMANCE: A MANAGEMENT PARADIGM REVISITED

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Journal:	*International Journal of Production Research*
Manuscript ID:	TPRS-2011-IJPR-0327.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	11-Jul-2011
Complete List of Authors:	Obermaier, Robert; University of Passau, Chair for Accounting and Control Donhauser, Andreas
Keywords:	INVENTORY MANAGEMENT, PERFORMANCE ANALYSIS
Keywords (user):	

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Abstract. According to the "zero inventory" paradigm, inventory reflects waste and should be eliminated in order for performance to rise. In this study we investigate the effect of inventory holding on firm performance, analyzing 3,057 firm years of data. Interpreting performance as a function of inventory, results show that firms with the lowest inventory have the worst performance (and vice versa). When understanding inventory as a function of performance, results indicate that low-performing firms carry the least inventory, whereas high-performing firms have the highest stocks. Besides questions of causality, our results do not support a paradigm which suggests that firms should move toward zero inventory.

1. INTRODUCTION

Thirty years ago legions of managers and scientists started a pilgrimage to Japanese manufacturing plants in order to study the tremendous success of Japanese firms at that time. Impressed by drastically reduced inventory levels, the Western pilgrims coined a new management paradigm which was called zero inventory (Hall 1983). The core principle of zero inventory is that inventory reflects waste and should be eliminated, causing productivity to rise (Nakane & Hall 1983; Schonberger 1983; De Haan & Yamamoto 1999). However, inventory also has functions in regard to operations in manufacturing firms, e.g. to avoid costly setups or multiple orders and shipments, or simply to cope with uncertainty and secure acceptable service levels when balancing supply and demand. Accordingly, numerous normative models were developed in operations research to determine optimal lot sizes and inventory levels (e.g. Silver et al. 1998, Silver 1981). Nevertheless, the zero inventory paradigm does not accept this view of necessary costs of carrying inventory, assuming inventory is necessary due to unsolved problems. Lieberman and Demester (1999, p. 466) point out that "inventories prevent the discovery of problems on the shop floor and thus [are] detrimental to productivity." In the context of determining optimal lot sizes, such unsolved problems could be time-consuming setup processes which it would be better to eliminate or reduce to a minimum. In consequence, the classical lot sizing problem would go up in smoke.

Whether inventory was always "waste" or not, if the zero inventory paradigm tended to be a reliable proposition, one could associate inventory reductions with improved firm performance in general. Hence, our main research questions are: (1) Do firms with lower inventories show superior financial performance? (2) Does the financial performance of firms increase when their inventories decrease?

This empirical study is motivated by the lack of empirically confirmed answers to such questions, although the zero inventory paradigm has been accepted for nearly thirty

years, even currently experiencing its second heyday in business practice (Demeter & Matyusz 2010; Obermaier & Donhauser 2009). To the best of our knowledge this study is the first to lead an empirical investigation into inventory development and its relation to financial performance for corporations in Germany, as a major European economy. Furthermore, this study is intended to critically analyze the zero inventory paradigm as a core management paradigm which served as a starting point for the development of several related paradigms such as "just in time" or "lean production" (Womack & Jones 1994). From a critical rationalist perspective, this study is also an attempt at sorting out falsified theories – "the good into the pot, the bad into the crop".

The article is organized as follows: In the subsequent section we review the existing body of literature and summarize our main findings. In Sections 3 and 4 we develop our hypotheses, and describe our research methodology and the data sources used. The results are presented in Section 5. Their implications and limitations are discussed in Section 6. We conclude with a summary of our key findings and further research opportunities in Section 7.

2. LITERATURE REVIEW AND HYPOTHESIS

Robert W. Hall, one of the first American authors to describe the Japanese just-in-time production system, and coin the terms "zero inventory" and "stockless production", did not of course mean that firms should literally run their business without inventory: zero inventory implies zero input, throughput and output. Instead, Hall (1983, p. 1) argued: "Zero inventories connotes a level of perfection not ever attainable in a production process. However, the concept of a high level of excellence is important because it stimulates a quest for constant improvement through imaginative attention to both the overall task and to the minute details." Obviously, achieving zero inventories requires a high level of excellence which is often summarized in the literature in terms of seven other "zeros": zero defects, zero excess, zero

setup times, zero breakdowns, zero handling, zero lead time, and zero surging (Hopp & Spearman 2008). But following this "zero logic", inventory levels act as a key indicator of business performance. The analogy of high water levels hiding unsolved problems is often used in this context. Undoubtedly, the zero inventory paradigm has caused quite a stir in business practice for many years. More than that, it seems to be an evergreen, which also served as a starting point for the development and application of several "lean techniques" in order to achieve the unachievable goal of zero inventory.

Twenty years ago, Blinder and Maccini (1991, p. 79) found that the inventory to sales ratios of US companies' inventories showed no decreasing trend between 1959 and 1986, a result "which casts serious doubt on buffer stock theories of inventory behavior since computerization should have reduced the need for inventories as buffers". This critical assessment of research on inventories evoked other empirical studies on inventory performance over time – mainly in the US. Bairam (1996), for example, finds significant downtrends in inventory to sales ratios of individual US manufacturing firms between 1976 and 1992. Hirsch (1996) discovers improvement in work-in-process and raw material inventories at least for some manufacturing sectors (e.g. motor vehicles, rubber and plastics) in the US industry from the late 1960s to the early 1990s but not for manufacturing as a whole. Using aggregate industry data, Rajagopalan and Malhotra (2001) observe decreasing raw material and work-in-process inventories during the period between 1961 and 1994 in the majority of the 20 manufacturing sectors analyzed. Finished goods inventories decreased in some industry sectors and increased in a few others but did not show a clear, general trend . Irvine (2003) identifies downtrends in inventory holding for manufacturers and merchant wholesalers carrying durable goods in the US since the mid 1980s, whereas nondurable goods retailers', wholesalers', and even manufacturers' finished goods inventories and to some extent work-in-process inventories increased. After investigating the inventories of 7,433 US

manufacturing firms, Chen et al. (2005, p. 1021) report that while "the medians of raw materials, finished goods, and total inventory days drop, the means actually rise between 1981 and 2000", as means may be influenced by outliers that are focusing on medians. Based on aggregate US industry level data, Shah and Shin (2007) find that inventory levels trended downward in the manufacturing sector, which occurred rapidly during the 1990s. Performing the first study for a major European economy, Obermaier and Donhauser (2009) analyze inventory performance of 100 German stock-listed corporations between 1993 and 2005. Their findings indicate that the total inventory to sales ratio decreased in four out of six industry sectors, whereas on the firm level, they find that half of the firms based in industry sectors that are especially well known for their use of just-in-time (JIT) techniques show a significant decrease in total inventories.

A second stream of research can be identified, examining the specific benefits of JIT adoption and other modern manufacturing technologies on inventory performance. Huson and Nanda (1995), for example, study a sample of 55 JIT adopters, discovering increased inventory turnover subsequent to their JIT implementation. Furthermore, they find a significant correlation between inventory turnover improvements and increasing earnings per share. Balakrishnan et al. (1996), on the other hand, also compare a sample of 46 JIT adopters with a sample of non-adopters of the same size but observe no significant effects on financial performance. This also holds for a survey conducted by Sakakibara et al. (1997). Lieberman and Demeester (1999) study 52 Japanese automotive companies over a time period from the late 1960s to the early 1980s, shedding light on the linkage between inventory and productivity: As expected from the standpoint of the zero inventory paradigm, they find firms reducing inventory substantially were able to improve labor productivity significantly. Following this paradigm, inventories are not seen as residua of production and operations activities, but as important contributors to a firm's overall success. Accordingly, Fullerton and

McWatters (2001) show that extensive adopters of JIT reduce their work-in-process inventories and increase their profitability substantially. Biggart and Gargeya (2002) find decreasing total and raw material inventory to sales ratios after JIT implementation, whereas this does not hold for work-in-process and finished goods inventories.

As most of these JIT studies are based on quite small sample sizes in the automotive industry in most cases, subsequent studies tried to broaden the industry scope and increase sample sizes. Although this third stream of inventory research is concerned with the relationship between inventory and firm performance, the variables are measured indirectly, based on survey data rather than financial metrics. Demeter (2003) notes that the existence of a clear manufacturing strategy should be associated with higher ROS, but finds no difference between firms with a clear manufacturing strategy and those without in regard to inventory turnover. Fullerton et al. (2003) detect a significant positive effect of lower inventory levels on ROA and ROS in their survey, whereas Vastag and Whybark (2005) find no significant overall relationship between inventory turnover and firm performance. Demeter and Matyusz (2010), however, show that firms applying lean practices have higher inventory turnover than those that do not rely on lean techniques.

The fourth and most recent stream of inventory research is concerned with the explicit relationship between inventory and firm performance. Chen et al. (2005) analyze this relationship from a capital market perspective and create portfolios of firms based on their relative inventory performance, finding abnormally high inventories associated with poor stock market performance. However, they also explore firms with slightly lower than average inventories that have good stock returns, while firms with the lowest inventories have only ordinary returns.

Analyzing the link between inventory and financial performance, Shah and Shin (2007) discover improved inventory performance (i.e. lower inventory levels) with positively related

financial performance for the US manufacturing industry as a whole. Swamidass (2007) argues that inventory holding could be a function of the firms' financial performance, observing that top performers reduced inventories significantly during the period 1981 to 1998, whereas low performers showed a surprising increase in inventories, carrying more inventory than top-performing firms. Considering the levels, Swamidass finds that bottom performers show higher inventory to sales ratios. Cannon (2008) finds no significant link between inventory improvements and firm performance of US manufacturing firms between 1991 and 2000. In his empirical study, better inventory performance was associated with better financial performance for some firms while for many firms this remained unchanged. Some firms showed even worse financial performance associated with better performing inventories. Capkun et al. (2009) continue this stream of inventory performance studies for US manufacturing firms. Over a 26-year period from 1980 to 2005 they find a significant relationship between lower inventory to sales ratios and the profitability of firms across a broad range of industries. Obermaier and Donhauser (2009) perform a sensitivity analysis to grasp some insights into the relationship between inventory reduction and financial performance, using firm-level data on German firms. Although the results of a ceteris paribus analysis should be handled with care, they find that the potential contributions of inventory improvements to the financial performance of firms would only be a small amount. Apart from their work we found no recent empirical study concerned with the financial effects of changes in inventory holdings on the performance of either German firms or any other major European firms. Obviously there is a lack of consensus regarding the relationship between inventory holding and overall firm performance. This article is an attempt to fill this gap by explicitly analyzing the relationship between inventory holding and firm performance for a large sample of German firms, using financial metrics.

While some researchers find that the contribution of inventory reductions to firm performance might be quite small when compared to other success factors (Lieberman & Demeester 1999), the majority follow the zero inventory paradigm, interpreting inventory as unnecessary waste and costly, and therefore expecting performance to increase when inventories decrease (Sugimori et al. 1977, Nakane & Hall 1983, Hayes 1981, Monden 1981a, b, Schonberger 1982, Wildemann 1988). Accordingly, JIT systems, in particular, have been widely established during the past decades. The main argument behind this paradigm is that inventory is only rendered necessary because of unsolved problems in several business processes; i.e. inventory holding does not solve problems, but hides difficulties on the shop floor. The range of examples of such problems goes from lengthy setup times to quality problems which make buffer inventories necessary. Thus, inventory is harmful to productivity, but solving such problems would lead to better business performance and make inventory holding dispensable to a certain degree.

Furthermore, inventory reduction programs are also widely established in order to release cash for alternative uses. Besides the effects on liquidity, inventory reduction programs are also expected to increase financial profitability. The logic behind this argument draws on the classical DuPont system of financial control and is quite obvious: decreasing inventories lead ceteris paribus to reduced capital requirements, causing profitability measures such as return on assets to increase (and vice versa). This also holds in a more sophisticated value-based management environment with residual income (e.g. Economic Value Added) as a key performance measure.

To sum up: While it is clear that ceteris paribus lower inventories cause higher return on assets, the proponents of zero inventory would also tend to associate inventory reduction with an increase in financial performance due to better business performance. Therefore, we postulate our main hypothesis:

Hypothesis: Firms with lower inventories show higher financial performance.

3. RESEARCH METHODOLOGY

3.1 Data

To analyze inventory performance over time, the study could either be executed at the firm level using disaggregated data or at the industry level using aggregated data. This study is based on disaggregated data at the firm level, mainly in order to guard against an aggregation bias, i.e. firms performing differently cancelling each other out in each sector. In the majority of cases, firm-level data are only publicly available for stock-listed corporations, which, of course, represent just a fractional amount of the total number of German companies. All data used were taken from Thomson Financial's Worldscope Global Database.

The sample chosen spans the time frame from 1989 to 2004 and consists of 3057 company years with complete data for all the variables of interest. The reason for setting the end of our time frame at 2004 was a compulsory legislative switch for all German stock listed companies from local GAAP (German HGB) to international GAAP (IAS/IFRS) in 2005. In order to avoid any accounting effects in the data, we limited our analysis to firm data based on local GAAP. Although there were still some financial statements based on local GAAP in 2005, we excluded this year from our statistical analysis due to the small sample size for this year. Because several firms had already switched to international GAAP some years before 2005, the number of firms in the sample using local GAAP has recently declined. The reason for the beginning of our time frame was the sufficient sample size ($n > 100$), which was not given for the years before 1989. The distribution of our sample over time is shown in Figure 1.

INSERT FIGURE 1 HERE

The firms in the sample are assigned to the Standard Industrial Classification (SIC) manufacturing division. The SIC manufacturing division includes firms "engaged in the mechanical or chemical transformation of materials or substances into new products", which can be split into two major groups. The first group covers firms $20 \leq SIC \leq 29$, which are mainly in the food products (SIC 20), textiles (SIC 22) and wearing apparel (SIC 23), wood products (SIC 24), furniture (SIC 25), paper (SIC 26), printing (SIC 27) and chemical (SIC 28) industries. The second group covers firms $30 \leq SIC \leq 39$, including manufacturing firms mainly in industries such as rubber and plastics (SIC 30), leather (SIC 31), stones, clay, and glass (SIC 32), primary metal (SIC 33), fabricated metal products (SIC 34), machinery (SIC 35), electronics and electrical equipment (SIC 36), transportation equipment (SIC 37), measuring instruments (SIC 38), and miscellaneous manufacturing (SIC 39) industries. The sample distribution over SIC codes on a two-digit basis is shown in Figure 2.

INSERT FIGURE 2 HERE

3.2 Measurement of Inventory Holding

Because inventory varies according to production and distribution levels, amongst other factors, it may increase (decrease) simply because sales have increased (decreased). Therefore, it is inappropriate to use absolute inventory measures (e.g. in euro values). Instead, we use relative inventory measures. One widely used ratio is inventory to sales, which measures the percentage of sales which could be served from stock on hand (see Bairam 1996; Irvine 2003; Chen et al. 2005, for example). If I_{it} and S_{it} denote total inventory (sum of raw materials, work-in-process, and finished goods) and sales, respectively, of firm i in year t, then the inventory to sales ratio is:

$$IS_{it} = \frac{I_{it}}{S_{it}}. \quad (1)$$

Generally speaking, a declining (rising) inventory to sales ratio over time means that inventories grow more slowly (faster) than sales. From an operations management point of view, we are especially interested in how long inventory is held. Accordingly, the inventory to sales ratio can be multiplied by 12 months or 365 days providing a measure of inventory reach for a given value of sales. One further advantage of the inventory to sales ratio is that it corrects for sector size and for the impact of inflation. Finally, the analysis is only affected by changes in price levels to a minor degree, given that prices of outputs vary according to the prices of inputs. As we are using annual data in this study we will not analyze inventory fluctuations, i.e. short-term oscillations, which are regularly used by analysts for short-term business cycle forecasting (Knetsch 2004). Instead, our focus is on long-term trends in inventory to sales ratios.

3.3 Measurement of Performance

Performance measurement is a huge topic in both the management accounting and operations or strategic management literature. Here, three fundamental theoretical approaches can be differentiated.

The goal-based approach measures performance by goals which a firm sets itself. The metrics used are widespread, but can be divided into two main groups. Whereas financial metrics are either based on balance sheet and P&L statement data (e.g. ROI, ROS) or on stock market values (e.g. EVA, market to book ratio), non-financial metrics focus on operational performance dimensions such as quality, time, or flexibility (Neely et al. 1995). Moreover, organizational theory has an even broader concept of business performance (Venkatraman & Ramanujam 1986). The systems approach measures business performance according to a firm's capacity for long-term survival in its surrounding environment (i.e. system). The

stakeholder approach argues that a firm should take into account the views of all the stakeholders of the business and not just the owners. Accordingly, this approach defines business performance as a firm's ability to achieve the goals of different stakeholder groups simultaneously.

The measurement problems of the latter perspectives are obvious. Furthermore, Murphy et al. (1996) report that most empirical studies use financial metrics such as ROI or ROS, which are consistent with the goal approach. In this study we also use financial data to measure performance. However, in order to account for the perils of a performance perspective which is too narrow (Venkatraman & Ramanujam 1986, p. 807), we decided to use Altman's Z-score as a financial but multidimensional performance measure (Altman 1968). One further advantage of this approach is that a multidimensional performance index is more robust than single performance measures such as ROI or ROS.

Altman's classic Z-score, originally developed to predict firm bankruptcy using financial data from annual reports, was based on a sample of 33 bankrupt and 33 ongoing firms. After conducting a multiple discriminant analysis based on five accounting ratios (X_1, …, X_5), the following discriminant function emerged:[1]

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5, \quad (2)$$

with: X_1 = working capital / total assets,

X_2 = retained earnings / total assets,

X_3 = EBIT / total assets,

X_4 = market value of equity / total debt,

X_5 = sales / total assets.

[1] Contrary to Altman's (1968) original function, all ratios here are decimal.

On the basis of this function Altman classifies 31 of the bankrupt firms and 32 of the ongoing firms correctly.[2] The higher the Z-score of a firm, the lower its risk of bankruptcy. Although the estimated coefficients are sample specific, this classic formula is considered to be robust and is still used by practitioners and researchers.

In subsequent years several derivatives of the classical Altman Z-score evolved. To apply it to non-listed firms the suggestion was to measure X_4 with the book value of equity as a proxy (Altman 2000). Based on Altman's original sample it followed model Z':

$$Z' = 0.717X_1 + 0.947X_2 + 3.107X_3 + 0.42X_4' + 0.998X_5, \quad (3)$$

with: X_1 = working capital / total assets,

X_2 = retained earnings / total assets,

X_3 = EBIT / total assets,

X_4' = book value of equity / total debt,

X_5 = sales / total assets.

As ratio X_5 was considered industry-specific later on, it was excluded from the following model, Z'', which was estimated as follows (Altman 2002):

$$Z'' = 6.56X_1 + 3.26X_2 + 6.72X_3 + 1.05X_4', \quad (4)$$

with: X_1 = working capital / total assets,

X_2 = retained earnings / total assets,

X_3 = EBIT / total assets,

X_4' = book value of equity / total debt.

In this study, we applied these three models to our sample in order to generate specific Z-scores. Hence, the coefficients had to be re-estimated. In a first step, all stock listed

[2] For this classification, a cut-off-value has to be estimated. See Altman (1968), p. 606, for example.

companies in our sample which filed for bankruptcy were identified (n = 27) and the last year of complete data prior to the start of bankruptcy proceedings was selected (t-1 or t-2; Altman 1968, p. 593). In a second step, a corresponding number of existing firms was randomly chosen. To make sure that the set of existing firms fitted in terms of size and industry, a *t*-test and a χ^2-test were performed. In cases where the null hypothesis was rejected, a new sample was randomly created. For every model we ran five randomly generated samples and executed a multiple discriminant analysis (see Appendix A).

Comparing these models, we found that model Z'' showed the best goodness of fit criteria (e.g. percentage of correct classification, Wilk's lambda). Hence, based on our sample, the revised discriminant formula for model Z'' is as follows:

$$Z''_{revised} = 2.538X_1 + 0.522X_2 + 1.681X_3 - 0.110X'_4 - 0.182. \quad (5)$$

It should be noted that it is not the purpose of this study to estimate the probability of a firm going bankrupt. Hence, the goodness of the discriminant function is of minor importance here. Instead, the goal is to generate a more objective and robust multiple performance index in order to rank the firms by financial performance and prosperity.

3.4 Method

To investigate our hypotheses, several time series regressions were run, in which the firms were ranked by inventory-to-sales ratios, and divided into three deciles (high, medium, and low) for each year of our time frame. Then the average Z-score was calculated for each year and each inventory decile. A regression analysis was conducted to detect trends in performance over time. A multivariate regression was also conducted.

4. RESULTS

Analyzing the time series of Z"-scores we found no significant differences between the means of the high (0.399) and medium (0.463) IS deciles, but high significant ($p < 0.01$) differences compared to the low IS decile (-0.589). Obviously, firms with medium to high inventories also have better performance criteria, whereas firms with the lowest inventories show the worst financial performance on average.

INSERT TABLES 1 & 2 HERE

Analyzing the time trends we found a constant performance trend for the high IS decile, whereas the low IS decile showed a strong significant decline in performance over time. For the medium IS decile we detected a slight but significant decline in performance. The difference between the high and medium groups was not significant. But comparing the high and medium groups to the low IS decile respectively, the differences were significant.

INSERT FIGURE 3 HERE

INSERT TABLE 3 HERE

Hence, interpreting financial performance as a function of inventory holding, the results suggest a positive relation between inventory holding and financial performance; i.e. those firms with the lowest inventory also show the worst performance (and vice versa). These results were also confirmed when a multiple regression was conducted, showing a highly

significant ($p < 0.01$) positive influence of inventory-to-sales on firm performance. These results are reported in Table 4.

INSERT TABLE 4 HERE

To investigate how much inventory successful companies are carrying, we have to reverse our analysis in terms of dependent and independent variables. Analyzing the IS ratios, we find no significant differences between the means of the high (0.207) and medium (0.189) Z" deciles, but highly significant ($p < 0.01$) differences compared to the low IS decile (0.086). Obviously, firms with medium to high financial performance have significantly higher inventories than low-performing firms – more than twice the size. While low-performing firms have an inventory turnover of almost 12 on average, it is less than five for high-performing firms.

INSERT TABLES 5 & 6 HERE

Although we detect highly significant decreasing IS ratios over time for our complete sample, there is no trend for low- and medium-performing firms. Nevertheless, firms with the highest financial performance show a significant downsizing of inventories, whereas the difference between high- and low-performing firms is significant.

INSERT FIGURE 4 HERE

INSERT TABLE 7 HERE

Understanding inventory as a function of a firm's financial performance, our results again suggest a positive relationship between inventory holding and financial performance, as low-performing firms carry the least inventory, whereas high- and medium-performing firms also have the highest inventory in stock.

5. DISCUSSION

Although we find significantly decreasing IS ratios over time, our results contradict the "critical argument on behalf of inventory reduction … that it will improve the financial position of firms" (Chen at al. 2005, p. 1025).

From a capital market perspective, Chen et al. (2005) create portfolios of firms based on their relative inventory performance, and find abnormally high inventories associated with poor stock market performance. Considering quite simple shareholder value logic or the classical DuPont system of financial control, this is not very surprising. Furthermore, Chen et al. (2005) find that firms with slightly lower than average inventories have good stock returns, while firms with the lowest inventories have only ordinary returns. Obviously, this U-shaped relationship does not support the zero inventory paradigm. Nevertheless, according to signaling theory, Tribo (2009) finds a kind of "window dressing" effect: Firms tend to reduce inventories before an IPO in order to signal low capital costs to future investors. Apparently, the capital market sanctifies abnormal high inventories but does not honor low inventory per

se. While the former is not in line with our results, the latter is so, which indicates that a certain level of inventory is needed to run business processes properly.

However, more than that, our results contradict the recent empirical studies of Swamidass (2007) and Capkun et al. (2009), both concerned with the relationship between the inventories and performance of US manufacturing firms. Whilst Swamidass (2007) argues that inventory holding could be a function of firms' financial performance, where lower inventory-to-sales ratios are associated with higher performance, Capkun et al. (2009) assume financial performance to be a negatively related function of inventory holding. While our results do not support the latter, we have some reason to discuss the former: First, our results are also in contrast to those of Swamidass (2007). We find a positive rather than negative relationship between inventory holding and firm performance: Increasing inventories lead to increasing financial performance (and vice versa). Our results suggest that inventories which are too low make it much more difficult to run business processes cost-efficiently. Second, our results support the interpretation of inventory holding as a function of financial performance. Like Swamidass (2007), we also found top-performing firms reducing their inventories, but on a higher level. Nevertheless, we argue that bottom performers suffer from low inventories, while he argues that bottom performers suffer from a variety of problems which make it hard for them to reduce inventories.

Besides the fact that correlation cannot prove causality, adhering to the idea of inventory holding as a function of financial performance, our results correspond to a certain inventory behavior in times of low financial performance: If general economic conditions become worse, firms with low financial performance may be forced to convert working capital into cash in order to generate liquidity. At first glance, it would stand to reason that reducing inventory might be the commonly chosen approach for that purpose. However, taking the resulting negative effects on business performance into account, for example

delayed production processes or lower service levels, a reduction in inventory turns out to be the wrong approach. On the other hand, firms showing strong financial performance could afford to hold higher inventories in order to run their processes well, and serve their customers at higher service levels. Of course, it could be argued that financially successful firms also could afford to invest in modern manufacturing technology, leading to lower inventories, which is Swamidass' (2007) central argument. Considering our divergent results, there may have been differences between the manufacturing organization and strategies of US and German firms during the time frame investigated.

Furthermore, our results also help to interpret previous results of Obermaier and Donhauser (2009). Analyzing the inventory performance between 1993 and 2005, and conducting several ceteris paribus sensitivity analyses, they find that the potential contributions of inventory improvements – even a reduction of 50 percent – to the financial performance of 100 German corporations are only very small. In the light of our discussion so far, this would become even worse if we took into account that a sole inventory reduction in the "real world" (without a ceteris paribus condition) would reduce performance due to several suboptimal processes. While it is clear that ceteris paribus lower inventories cause higher return on assets, this relation does not necessarily hold in the real world, which does not offer a ceteris paribus opportunity in most cases.

Obviously, inventory holding costs money but is not always a disadvantage, because inventories do have benefits as well. Hence, when interpreting financial performance as a function of inventory, the notion "lesser inventory is better" cannot be maintained. Instead the classic view of operations research, seeking for optimum lot sizes and inventory levels, regarding inventory as a costly but necessary buffer to smooth production levels (e.g. Silver et al. 1998, Silver 1981), seems to regain ground. With respect to this operations research view the following distinction might be helpful: inventory (in monetary units) as a component of

cost of capital ought to be minimized in an optimization calculus, while sufficient stock (in quantity units) has to be considered as a constraint.

According to our results, inventory performance can be seen as an indicator of financial performance, but not in the direction expected. Firms obviously need sufficient inventory to ensure the safety stock level required, and to run their businesses properly and successfully, especially in an uncertain environment. On the other hand, low inventories may result from too limited financial resources rather than from the implementation of a zero inventory strategy. Low-performing firms might just need to reduce inventory in order to increase liquidity.

Nevertheless, high-performing German firms also show decreasing inventories over time which have still remained at a higher level in the recent past than those of low performers. Considering Chen at al. (2000), this could be explained by the soaring role of information exchange with suppliers and customers, enabled by modern supply chain techniques (e.g. better forecasting techniques, advanced information and planning systems, closer and more collaborative relationships with customers or suppliers, automatic replenishment programs), which can help reduce inventories. Over the last few years, many companies have applied automatic replenishment programs, of which vendor-managed inventories (VMI) enjoy great popularity, to increase inventory turns (see Cheung & Lee 2002, for example). However, both alternatives – higher inventories or better information exchange – are investments which require capital expenditures and the need to appraise investments in such techniques. Hence, top performing firms may choose between inventory holding and modern supply chain techniques,[3] while low-performing firms might not be able to afford such opportunities.

[3] For some general aspects of this issue, see a formal model by Milgrom and Roberts (1988), in which inventories play a buffering role but whose importance is reduced when information exchange is increased.

6. CONCLUSIONS

The core principle of concepts such as "just-in-time" or "zero inventory" is that inventory reflects waste and should be eliminated, causing productivity to rise. Nevertheless, our empirical results suggest that inventory holding costs money but is not always a disadvantage, because inventories do have benefits as well. Hence, the notion "less inventory is better" is empirically refuted. Interpreting financial performance as a function of inventory holding, our results suggest a positive relationship between inventory holding and financial performance; i.e. those firms with the lowest inventory also show the worst performance (and vice versa). Understanding inventory as a function of financial firm performance, our results suggest a positive relationship between inventory holding and financial performance. Low-performing firms carry the least inventory, while high- and medium-performing firms have more than twice as much inventory in stock on average. In short, our empirical results do not support the zero inventory management paradigm.

For managers, these findings may be relevant for several reasons. First, and most importantly, managers should not believe in the zero inventory paradigm per se. Second, managers should not expect to improve their firm performance simply by reducing inventories; instead they will risk the opposite. Third, in order to find the optimum inventory level, managers are well advised to apply well-known operations research techniques. Fourth, managers of financially stable firms may choose between investments in inventory holding or modern supply chain techniques. Finally, managers of firms in financial trouble have to face the fact that reducing inventories may help them to increase short-term liquidity in hard times, but this will not help the firms in better times, when they need inventories to run production and serve their customers. As the recent financial crisis showed, many firms went bankrupt when the recession was over. Firms which had discharged their inventories during the

recession suddenly did not have sufficient liquidity to fill up their inventories when business cycles moved upwards again.

Our findings might also give a direction for further research, seeing inventory not so much as a predictor of financial performance but as what it mainly is: A "buffer" which allows firms to carry out several processes and functions well, for instance achieving smooth production levels, shifting production to periods in which production costs are expected to be relatively low, avoiding costly setups or multiple orders and shipments, or as a precaution against stock-outs. It may also be interesting to analyze the relationship between inventory holding and financial performance for different stages of the supply chain. On a raw materials level, the worst case scenario for just-in-time or zero inventory may result in a complete production system coming to a standstill. From a finished goods point of view, however, high inventories can result in obsolescence and cause component devaluation. From a strategic point of view it might be interesting to investigate whether innovative companies with higher profit margins do not (have to) take care of inventories as much as companies following a cost-leadership strategy with lower margins. Nevertheless, further research is necessary to gain more insight into the causal logic of the relationship between inventory holding and firm performance.

REFERENCES

Altman, Edward I. (1968): Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy, ***Journal of Finance***, 23 (4): 589–609.

Altman, Edward I. (2000): ***Predicting Financial Distress of Companies***, http://pages.stern.nyu.edu/~ealtman/Zscores.pdf (Access date: 2011-03-04).

Altman, Edward I. (2002): ***Revisiting Credit Scoring Models in a Basel II Environment***, http://www.stern.nyu.edu/fin/workpapers/papers2002/pdf/wpa02041.pdf (Access date: 2011-03-04).

Bairam, Erkin I. (1996): Disaggregate inventory-sales ratios over time: the case of US companies and corporations, 1976-92, ***Applied Economic Letters***, 3 (3): 167-169.

Balakrishnan, Ramji, Thomas J. Linsmeier and Mohan Venkatachalam (1996): Financial Benefits from JIT Adoption: Effects of Customer Concentration and Cost Structure, ***The Accounting Review***, 71 (2): 183-205.

Biggart, Timothy B., Vidyaranya B. Gargeya (2002): Impact of JIT on inventory to sales ratios, ***Industrial Management & Data Systems***, 102 (4): 197-202.

Blinder, Alan S. and Maccini, Louis J. (1991): Taking Stock: A Critical Assessment of Recent Research on Inventories, ***Journal of Economic Perspectives***, 5 (1): 73-96.

Capkun, Vedran, Ari-Pekka Hameri and Lawrence A. Weiss (2009): On the relationship between inventory and financial performance in manufacturing companies, ***International Journal of Operations & Production Management***, 29 (8): 789-806.

Cannon, Alan R. (2008): Inventory improvement and financial performance, ***International Journal of Production Economics***, 115 (2): 581-593.

Chen, Frank, Zvi Drezner, Jennifer K. Ryan and David Simchi-Levi (2000): Quantifying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead Times, and Information, ***Management Science***, 46 (3): 436-443.

Chen, Hong, Murray Z. Frank and Owen Q. Wu (2005): What actually happened to the Inventories of American Companies between 1981 and 2000?, ***Management Science***, 51 (7): 1015-1031.

Cheung, Ki Ling, Lee, Hau L. (2002): The Inventory Benefit of Shipment Coordination and Stock Rebalancing in a Supply Chain, ***Management Science***, 48 (2): 300-306.

De Haan, Job and Masaru Yamamoto (1999): Zero inventory management: facts or fiction? Lessons from Japan, ***International Journal of Production Economics***, 59 (1-3): 65-75.

Demeter, Krisztina (2003): Manufacturing strategy and competitiveness, ***International Journal of Production Economics***, 81-82 (1): 205-213.

Demeter, Krisztina and Zsolt Matyusz (2010): The impact of lean practices on inventory turnover, ***International Journal of Production Economics***, doi:10.1016/j.ijpe.2009.10.031.

Fullerton, Rosemary R. and Cheryl S. McWatters (2001): The production performance benefits from JIT implementation, ***Journal of Operations Management***, 19 (1): 81-96.

Fullerton, Rosemary R., Cheryl S. McWatters and Chris Fawson (2003): An examination of the relationships between JIT and financial performance, ***Journal of Operations Management***, 21 (4): 383-404.

Hall, Robert W. (1983): ***Zero Inventories***, McGraw Hill: New York.

Hayes, Robert H. (1981): Why Japanese factories work, ***Harvard Business Review,*** 59 (4): 56-66.

Hirsch, Albert A. (1996): Has inventory management in the US become more efficient and flexible? A macroeconomic perspective, ***International Journal of Production Economics***, 45 (1-3): 37-46.

Hopp, Wallace J. and Mark L. Spearman (2008): ***Factory Physics***, 3rd ed., McGraw Hill: New York.

Huson, Mark, Dhananjay Nanda (1995): The impact of Just-in-Time manufacturing on firm performance in the US, ***Journal of Operations Management***, 12 (3-4): 297-310.

Irvine, F. Owen (2003): Long term trends in US inventory to sales ratios, ***International Journal of Production Economics***, 81-82 (1): 27-39.

Knetsch, T.A. (2004): The Inventory Cycle of the German Economy, ***Deutsche Bundesbank Discussion Paper Series 1: Studies of the Economic Research Centre***, No. 09/2004.

Lieberman, Marvin B. and Lieven Demeester (1999): Inventory Reduction and Productivity Growth: Linkages in the Japanese Automotive Industry, ***Management Science***, 45 (4): 466-485.

Monden, Yasuhiro (1981a): What makes the Toyota production system really tick?, ***Industrial Engineering***, 13 (1): 36-46.

Monden, Yasuhiro (1981b): Adaptable Kanban system helps Toyota maintain just-in-time production, ***Industrial Engineering***, 13 (5): 29-46.

Murphy, Gregory B., Jeff W. Trailer and Robert C. Hill (1996): Measuring Performance in Entrepreneurship Research, ***Journal of Business Research***, 36 (1): 15-23.

Nakane, Jinichiro and Robert W. Hall (1983): Management specs for stockless production, ***Harvard Business Review***, 61 (3): 84-91.

Neely, Andy, Mike Gregory and Ken Platts (1995): Performance measurement system design: A literature review and research agenda, ***International Journal of Operations and Production Management***, 25 (12): 1228-1263.

Obermaier, Robert and Andreas Donhauser (2009): Disaggregate and aggregate inventory to sales ratios over time: the case of German corporations 1993–2005, ***Logistics Research***, 1 (2): 95-111.

Rajagopalan, S. and Arvind Malhotra (2001): Have U.S. Manufacturing Inventories Really Decreased? An Empirical Study, ***Manufacturing & Service Operations Management***, 3 (1): 14-24.

Sakakibara, Sadao, Barbara B. Flynn, Roger G. Schroeder and William T. Morris (1997): The Impact of Just-in-Time Manufacturing and Its Infrastructure on Manufacturing Performance, ***Management Science***, 43 (9): 1246-1257.

Schonberger, Richard J. (1982): ***Japanese Manufacturing Techniques***, Free Press.

Shah, Rachna and Hojung Shin (2007): Relationships among information technology, inventory, and profitability: An investigation of level invariance using sector level data, ***Journal of Operations Management***, 25 (4): 768-784.

Silver, Edward A. (1981): Operations Research in Inventory Management: A Review and Critique, ***Operations Research***, 29 (4): 628-645.

Silver, Edward A., David F. Pyke and Rein Peterson (1998): ***Inventory Management and Production Planning and Scheduling***, 3rd ed., Wiley.

Sugimori, Y., K. Kusunoki, F. Cho and S. Uchikawa, S. (1977): Toyota production system and Kanban system: Materialization of just-in-time and respect-for-human system, ***International Journal of Production Research***, 15 (6): 553-564.

Swamidass, Paul M. (2007): The effect of TPS on US manufacturing during 1981-1998: inventory increased or decreased as a function of plant performance, ***International Journal of Production Research***, 45 (16): 3763-3778.

Tribo, Josep A. (2009): Firms' stock market flotation: Effects on inventory policy, ***International Journal of Production Economics***, 118 (1): 10-18.

Vastag, Gyula and D. Clay Whybark (2005): Inventory management: Is there a knock-on effect?, ***International Journal of Production Economics***, 93-94 (8): 129-138.

Venkatraman, N. and Vasudevan Ramanujam (1986): Measurement of Business Performance in Strategy Research: A Comparison of Approaches, ***Academy of Management Review***, 11 (4): 801-814.

Wildemann, Horst (1988): Just-in-time production in West Germany, ***International Journal of Production Research***, 26 (3): 521-538.

Womack, James P. and Daniel T. Jones (1994): From Lean Management to Lean Enterprise. ***Harvard Business Review***, 72 (2): 93-103.

APPENDIX A

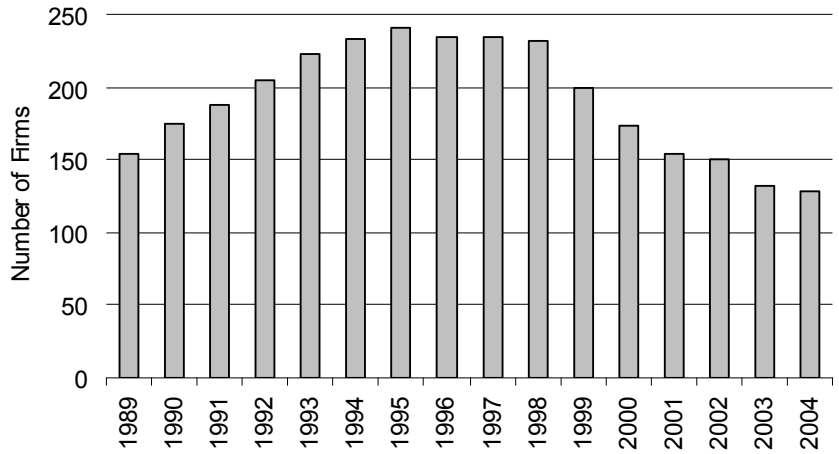
Model Z	Run	WC/TA	RE/TA	EBIT/TA	MC/TD	NS/TA	n	Percent Correct	Wilk's Lambda	Significance
	1	0.019	0.969	-0.048	0.540	0.051	54	72.2%	0.716	0.005
	2	-0.225	1.002	-0.056	0.514	0.281	54	74.1%	0.696	0.003
	3	0.440	0.231	0.529	0.283	0.222	54	75.9%	0.721	0.006
	4	0.357	0.473	0.316	0.337	0.092	54	72.2%	0.711	0.005
	5	0.183	0.449	0.390	0.484	0.471	54	70.4%	0.696	0.003
Average							54	73.0%		

Model Z'	Run	WC/TA	RE/TA	EBIT/TA	CE/TD	NS/TA	n	Percent Correct	Wilk's Lambda	Significance
	1	0.185	0.983	-0.091	0.105	-0.115	54	72.2%	0.761	0.019
	2	0.077	1.059	-0.129	-0.079	0.221	54	70.4%	0.737	0.010
	3	0.654	0.278	0.477	-0.150	0.166	54	77.8%	0.731	0.008
	4	0.608	0.499	0.256	-0.274	0.028	54	72.2%	0.721	0.006
	5	0.410	0.541	0.280	-0.006	0.326	54	66.7%	0.732	0.009
Average							54	71.9%		

Model Z''	Run	WC/TA	RE/TA	EBIT/TA	CE/TD		n	Percent Correct	Wilk's Lambda	Significance
	1	0.177	0.958	-0.059	0.138		54	72.2%	0.763	0.009
	2	0.064	1.118	-0.169	-0.097		54	70.4%	0.747	0.006
	3	0.692	0.245	0.496	-0.178		54	81.5%	0.736	0.004
	4	0.614	0.501	0.253	-0.278		54	72.2%	0.721	0.003
	5	0.460	0.643	0.209	-0.086		54	72.2%	0.753	0.007
Average							54	73.7%		

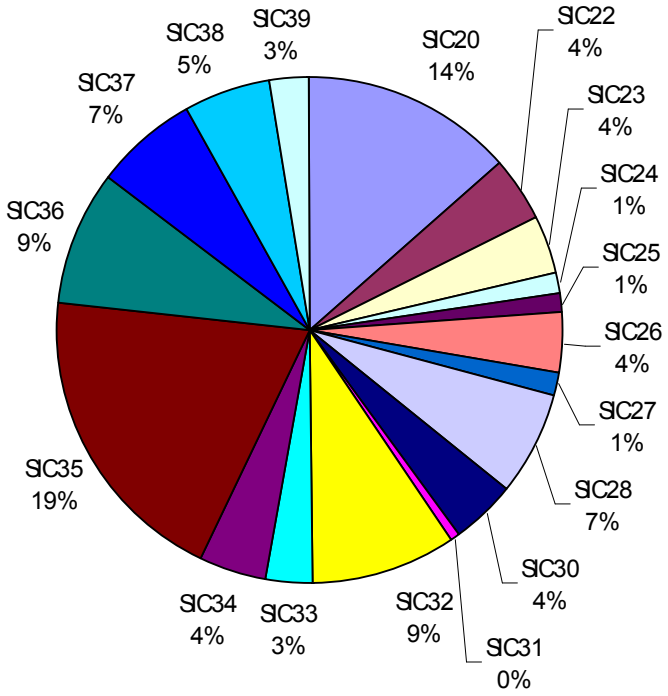
Multiple Discriminant Analysis for each Altman Z model (standardized canonical coefficients)
Significance of coefficients not reported here. Note: WC/TA = Working Capital / Total Assets, RE/TA = Retained Earnings / Total Assets, EBIT / TA = Earnings before Interest and Tax / Total Assets, MC/TD = Market Value of Capital / Total Debt, CE/TD = Capital Employed / Total Debt, NS/TA = Net Sales / Total Assets

FIGURE 1



Sample distribution over time

FIGURE 2

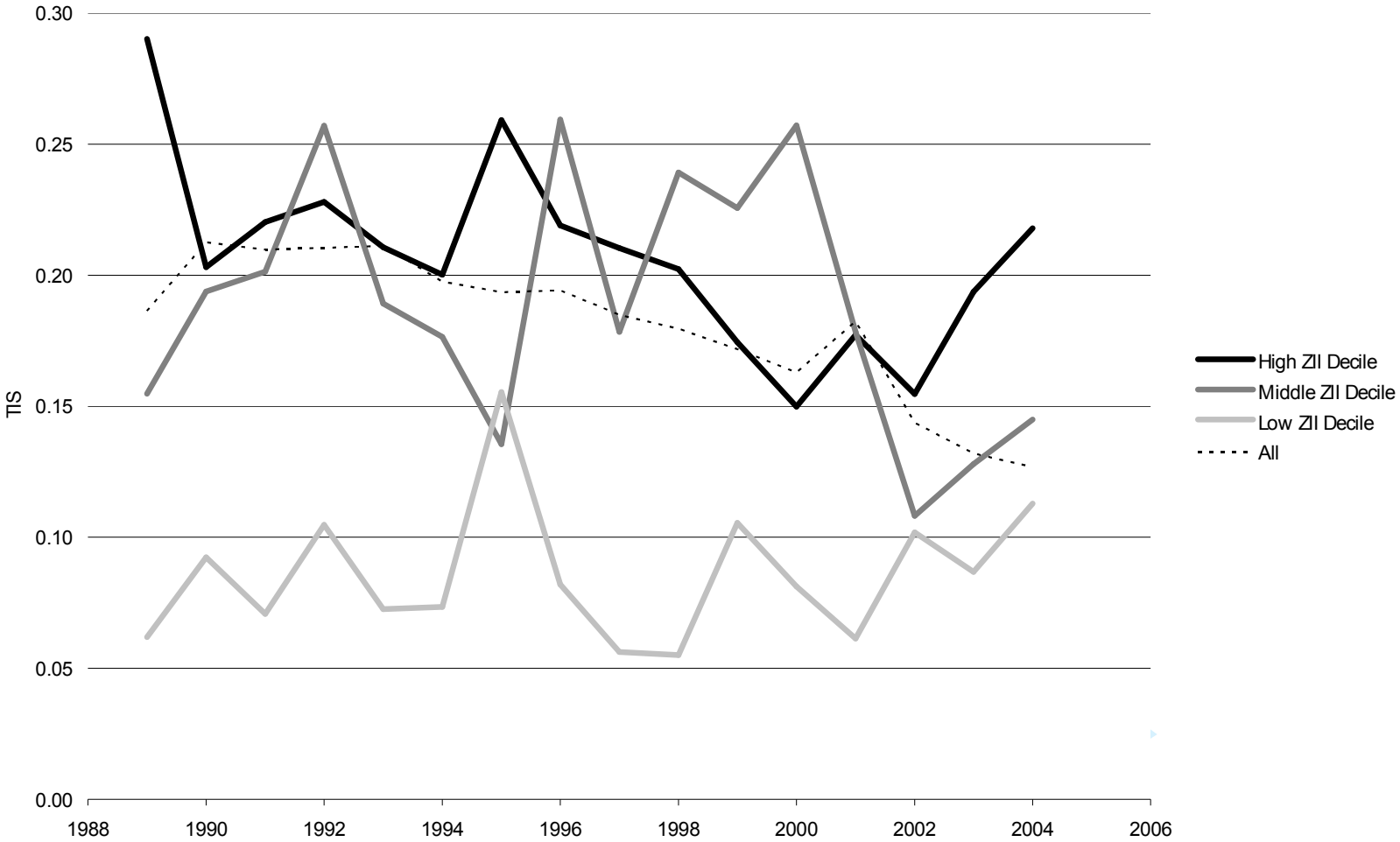


Sample distribution over two digit SIC Codes

FIGURE 3

Time series of Z"-scores from 1989 – 2004

FIGURE 4



Time series of IS scores from 1989 – 2004

TABLE 1

Year / ZII	High IS Decile	Middle IS Decile	Low IS Decile	All
MIN	0.076	0.278	-1.682	-0.029
MAX	0.673	0.644	-0.070	0.486
MEAN	0.399	0.463	-0.589	0.302
MEDIAN	0.420	0.460	-0.417	0.330
STD. DEV.	0.142	0.093	0.427	0.139
VAR. COEFF.	0.357	0.202	-0.725	0.459

Z"-Score performance of IS deciles: Descriptive statistics 1989-2004.

TABLE 2

	High - Low	High - Mid	Mid - Low
T	7.931	-1.429	11.055
p	0.000	0.174	0.000
Sig	***		***

T-Test of mean Z"-scores

TABLE 3

	High IS Decile	Middle IS Decile	Low IS Decile	All	High - Low	High - Mid	Mid - Low
β	0.001	-0.010	-0.059	-0.026	0.060	0.011	0.048
Sig		**	***	***	**		**
T	0.153	-2.174	-3.057	-6.827	2.611	1.197	2.853
p	0.881	0.047	0.009	0.000	0.021	0.251	0.013
SF	0.008	0.005	0.019	0.004	0.023	0.010	0.017
R^2	0.002	0.252	0.400	0.769	0.327	0.093	0.368
R^2adj.	-0.070	0.199	0.357	0.752	0.279	0.028	0.323

Time series analysis of Z"-score performance grouped by IS deciles 1989-2004.

TABLE 4

	non-standardized		stand.		
	β	s. e.	β	T	p
(constant)	-.832	.130		-6.420	.000
TIS	.506	.124	.076	4.071	.000
LNSAL	.099	.010	.189	10.409	.000
SIC20	-.730	.059	-.274	-12.468	.000
SIC22	-.030	.085	-.007	-.359	.720
SIC23	.184	.086	.039	2.121	.034
SIC24	-.191	.149	-.022	-1.281	.200
SIC25	-.066	.146	-.008	-.451	.652
SIC26	-.236	.087	-.050	-2.714	.007
SIC27	-.540	.134	-.071	-4.032	.000
SIC28	-.229	.071	-.062	-3.242	.001
SIC30	-.175	.083	-.039	-2.113	.035
SIC31	.664	.224	.051	2.968	.003
SIC32	-.121	.063	-.038	-1.919	.055
SIC33	-.342	.097	-.064	-3.526	.000
SIC34	-.205	.083	-.046	-2.483	.013
SIC36	-.057	.063	-.018	-.902	.367
SIC37	-.202	.070	-.056	-2.883	.004
SIC38	-.067	.075	-.017	-.893	.372
SIC39	.275	.102	.048	2.699	.007

Multivariate Regression Analysis
Dependent variable = Z". ANOVA: F-Test = 24.881 (p = 0.000). Adjusted R^2 = 0.129. Note: TIS = Total inventory to sales ratio. LNSAL = natural logarithm of sales (as control variable of firm size), SIC code dummies on a two-digit basis (as control variables for industry effects, s. e. = standard errors).

TABLE 5

Year / TIS	High ZII Decile	Middle ZII Decile	Low ZII Decile	All
MIN	0.150	0.108	0.055	0.127
MAX	0.290	0.259	0.155	0.213
MEAN	0.207	0.189	0.086	0.181
MEDIAN	0.207	0.184	0.082	0.186
STD. DEV.	0.034	0.047	0.025	0.027
VAR. COEFF.	0.165	0.247	0.294	0.147

IS ratios of Z"-deciles: Descriptive statistics 1989-2004

TABLE 6

	High - Low	High - Mid	Mid - Low
T	11.707	1.115	6.820
p	0.000	0.283	0.000
Sig	***		***

T-Test of mean IS ratios

TABLE 7

	High ZII Decile	Middle ZII Decile	Low ZII Decile	All	High - Low	High - Mid	Mid - Low
β	-0.005	-0.003	0.001	-0.005	-0.005	-0.002	-0.003
Sig	**			***	**		
T	-2.937	-1.004	0.542	-6.711	-2.944	-0.554	-1.041
p	0.011	0.332	0.596	0.000	0.011	0.588	0.316
SF	0.002	0.003	0.001	0.001	0.002	0.004	0.003
R^2	0.381	0.067	0.021	0.763	0.382	0.021	0.072
R^2adj.	0.337	0.001	-0.049	0.746	0.338	-0.048	0.006

Time series analysis of IS grouped by Z"-deciles 1989-2004