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Disaggregate and aggregate inventory to sales ratios over time: the case of German corporations 1993–2005

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Abstract Although inventory reduction has been a major topic in production and operations management research for many years, there is a lack of empirically confirmed answers for questions such as: Have inventories in fully industrialized economies such as Germany decreased, overall, during the past decades? To the extent, inventory reductions were successfully realized, in which industries did they occur? Are there differences in inventory reduction achievements between raw materials, work-in-process, or finished goods? Are there measurable effects of inventory reductions upon the financial performance? To the best of our knowledge, this empirical study is the first one to investigate long-term inventory development on a firm as well as on industry level in a major European economy. It is based on data from German corporations and provides answers to the research questions stated above. The study's findings indicate that total inventory to sales ratio decreased in a statistically significant extent in four out of six industry sectors during the time frame investigated. Further results suggest that the overall impact of inventory reductions to the financial performance of companies is only of a small degree.

Keywords Inventory · Manufacturing · Just-in-time · Supply chain · Logistics · Time series analysis

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1 The premise of inventory reduction as a driver of business performance

Inventory reduction has been a major topic in production and operations management research as well as in the academic literature on logistics and supply chain management for many years. Myriads of articles and case studies have been written about firm's needs and efforts to reduce inventories. In the operations research literature, numerous normative models were developed to determine optimal lot sizes and inventory levels. The belief that inventory reflects waste and should be eliminated to increase productivity is the fundamental premise of popular concepts such as "just-in-time" (JIT) or "zero inventory" [8, 21]. This article is motivated by the observation that, despite a long tradition of research related to inventory issues, there is lack of empirically confirmed answers to questions such as: Have inventories in fully industrialized countries such as Germany actually decreased, overall, during the past decades? Has inventory reduction developed differently for raw materials (RMs), work-in-process (WP), or finished goods (FGs), respectively? Are there measurable effects of inventory reductions upon the financial performance?

The study presented here is believed to be the first one to empirically investigate long-term inventory development in a major European economy. It provides answers to the research questions stated above, using firm level data from a sample of German corporations as opposed to aggregated industry level data. Nevertheless, it also analyzes inventory developments by industry sectors and by stages of the typical industrial value chain, i.e., RMs, WP, and FGs.

The article is organized into six sections: the subsequent Sect. 2 reviews the existing body of literature and summarizes major findings. In Sect. 3, we describe our research

methodology as well as the data sources used and develop several hypotheses regarding inventory trends during the time frame investigated. The results are presented in Sect. 4. Their implications will be discussed in Sect. 5. We conclude with limitations and further research opportunities in Sect. 6.

2 Inventory performance in the academic literature

To the best of our knowledge there is no recent empirical study concerned with inventory performance of firms of any major European economy. Regarding the US manufacturing industry, however, there are several studies examining the development of inventory levels.

In their critical assessment of research on inventories, Blinder and Maccini [4, p. 79] state that the inventory to sales ratio of US companies' inventories shows no decreasing trend between 1959 and 1986, a result "which casts serious doubt on buffer stock theories of inventory behavior because computerization should have reduced the need for inventories as buffers". This statement served as point of departure for a series of other studies primarily concerned with inventory levels in the US. In contrast to Blinder and Maccini [4], Bairam [1] finds significant downtrends in inventory to sales ratios of individual US manufacturing firms between 1976 and 1992. Hirsch [13] registers an improvement in WP and RM inventories for some sectors of the US manufacturing industry from the late 1960s to the early 1990s (e.g., motor vehicles, rubber and plastics). Having investigated the inventories of 7.433 US manufacturing firms, Chen et al. [7, p. 1021] report that while "the medians of RMs, FGs, and total inventory days drop, the means actually rise between 1981 and 2000", as means may be influenced by outliers they are focusing on medians. Recently, from a capital market view, using a sample of US manufacturing firms for the period 1994–2004, Tribó [28] finds evidence that after a firm was listed on the stock market it shows decreasing inventory levels.

In addition to this kind of inventory studies, a second stream of research is dedicated to the benefits of JIT adoption on inventory performance. Huson and Nanda [14] studied a sample of 55 firms that adopted JIT manufacturing and find out that these firms increased their inventory turnover subsequent to JIT implementation. Balakrishnan et al. [2] compare a sample of 46 JIT adopters with a sample of non-adopters of the same size and observe no significant effects on financial performance. Biggart and Gargeya [3] find decreasing total and RM inventory to sales ratios after JIT implementation, whereas this does not hold for WP and FGs inventories.

Finally, a third stream of research deals with the relationship of inventory and firm performance. Lieberman and Demeester [16] studied 52 Japanese automotive companies over a time period from the late 1960s to the early 1980s, shedding light on the link between inventory and productivity: firms reducing inventory substantially were able to improve labor productivity significantly. Chen et al. [7] created portfolios of firms based on their relative inventory performance and find abnormally high inventories associated with poor stock market performance. Swamidass [27] argues that inventory holding could be a function of firms' financial performance: top performers decreased inventories significantly, whereas low performers surprisingly showed increasing inventories. Cannon [6] also analyzes the link between inventory and financial performance, finding no relationship between improvements in inventory performance and improvements in overall firm performance.

3 Research hypotheses and the method of analysis

3.1 Hypotheses

It is according to common sense that inventory policy has to deal with a number of trade-off decisions balancing demand and capacity as well as costs and customer service. However, high inventories are often seen as poor operational performance in general because of tied-up capital, excess holding and carrying costs, and furthermore covering/hiding unnoticed or unsolved process problems. Hence, to release cash for alternative uses and to uncover hidden problems by lowering inventory levels, JIT systems, in particular, have been widely established in different industries [12, 18, 19, 25]. Accordingly, we want to know, if inventories in German firms actually decreased during the time frame investigated. Thus, we set forth the following hypotheses.

3.1.1 Hypothesis 1

In each of the German firms examined, (a) total inventory to sales ratios, (b) RM inventory to sales ratios, (c) WP inventory to sales ratios, and (d) FGs inventory to sales ratios show a decreasing trend between 1993 and 2005.

3.1.2 Hypothesis 2

On an aggregated level we correspondingly formulate Hypothesis 2.

In each of the industries examined, (a) total inventory to sales ratios, (b) RM inventory to sales ratios, (c) WP inventory to sales ratios, and (d) FGs inventory to sales ratios show a decreasing trend between 1993 and 2005.

3.1.3 Hypothesis 3

Further on, we are interested in the stage where inventory reduction mainly has taken place: RMs, WP, or FGs. From the production and operations management literature, we know that JIT production techniques focus mainly on reducing WP inventory and cycle times [20, 26, 29]. The adoption of JIT purchasing principles is motivated by a desire to reduce RM inventories, as well. From Little's [17] "law" we can derive that a reduction of cycle time leads to lower WP inventories. Nevertheless, if customers refuse to accept early deliveries because of their "inventory consciousness", orders that are finished ahead of their due dates are forced to wait in FGs inventory before shipping. A relatively poor performance in FGs inventories may further be expected due to increasing product variety, number of plants or warehouse locations under the condition of constant or growing customer service levels. Furthermore, WP inventory seems to be more affected by factors within a firm's control when compared to FGs inventories. Hence, we expect WP (FGs) inventories to perform relatively best (worst) and therefore we formulate Hypothesis 3.

In each of the German firms examined, (a) WP inventory ratios when compared to RM inventory ratios, (b) WP inventory ratios when compared to FGs inventory ratios, and (c) RMs inventory ratios when compared to FGs inventory ratios show a greater decreasing trend between 1993 and 2005.

3.1.4 Hypothesis 4

Correspondingly, on an aggregated level we formulate Hypothesis 4.

In each of the industries examined, (a) WP inventory ratios when compared to RM inventory ratios, (b) WP inventory ratios when compared to FGs inventory ratios, and (c) RMs inventory ratios when compared to FGs inventory ratios show a greater decreasing trend between 1993 and 2005.

3.2 Data and sample

For analyzing inventory performance over time, the study could be executed either on firm level using disaggregated data or on industry level using aggregated data. This study is based on disaggregated data on firm level, mainly to guard against an "aggregation bias", i.e., differently performing firms canceling each other out per sector. In the majority of cases, firm level data are publicly available only for stock-listed corporations, which, of course, represent just a fractional amount of all German companies. The sample chosen covers the time frame from 1993 to 2005. All data used were taken from Thomson Financial's Worldscope Global Database. In several cases, manual correction of data was required based on print or online versions of the firms' annual financial reports due to false or implausible data from the data base. If this was not possible, firms were eliminated from the sample. Furthermore, to estimate the trend coefficients, firms were excluded when inventory data were not available for the whole time frame. Finally, the annual time series data cover 100 firms listed at the German stock market. The firms in the sample can be assigned to the Standard Industrial Classification (SIC) manufacturing division that includes firms engaged in the mechanical or chemical transformation of materials or substances into new products. This division can be split into two groups. The first group covers firms $20 \leq \text{SIC} \leq 29$, which are mainly in the food products (SIC 20), textiles (SIC 22) and wearing apparel (SIC 23), and chemical (SIC 28) industries. The second group covers firms $30 \leq \text{SIC} \leq 39$, including manufacturing firms primarily in industries such as rubber and plastics (SIC 30), 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.

3.3 Method of analysis

A linear regression model with time (i.e., year) as independent variable is applied to investigate the rate of change in inventory ratios over time. Because inventory varies among others with production and distribution levels, it is necessary to use relative inventory measures. A widely used ratio is inventory to sales, which measures the percentage of sales served from stock on hand.[1] Let I_{it} and S_{it} denote the inventory and the sales, respectively, of firm i in year t, the inventory to sales ratio is:

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

A declining (rising) inventory to sales ratio over time means good (bad) news in so far as sales grow faster (slower) than stocks. The short-term expectation is that production rates will be increased (cut back). For the long-term, decreasing trends in inventory to sales ratios may indicate improved efficiency. In order to better understand the degree of improvement at each of the different

[1] For some applications, the inventory to sales ratio is multiplied by 12 months or 365 days providing a measure of inventory coverage for a given value of sales. A further advantage of the inventory to sales ratio is that it corrects for sector size. Finally, the analysis is only to a minor degree affected by changes in price levels provided that prices of outputs vary according to the prices of inputs.

inventory stages as well as potential shifts between them, we analyze different inventory to sales ratios separately for total inventories as well as its constituents: RM, WP, and FGs. In order to focus on the material aspects of inventory development, it has to be emphasized that total inventory is defined here as the sum of these three components.[2]

Besides firm level data, we are also interested in the inventory trends of the corresponding industries. In order to calculate aggregate inventory to sales ratios in period t for a certain industry j, inventory held in the industry's firms $i = 1, 2, \ldots, n$, are summed up and then divided by the sum of sales across the n firms:

$$IS_{jt}^{\text{aggr}} = \frac{\sum_{i=1}^{n} I_{it}}{\sum_{i=1}^{n} S_{it}}. \tag{2}$$

We aggregate our data according to the SIC codes on a two digit basis. As we did not establish a class with less then ten companies, the result of the aggregation spans six industry classes, whereas we have merged the SIC codes 22 and 23 together due to their similarity.

To assess the corresponding overall trend coefficients for our sample over time, we applied the following simple linear regression model for total inventory levels as well as for each of the three inventory types:

$$IS_{it} = \alpha_i + \beta_{it} \cdot t + \varepsilon_{it}, \tag{3}$$

In Eq. 3, t represents the time period (year), α the intercept, and β the slope, i.e., the trend coefficient, of firm i. Because we applied regression analysis on time series data, we checked for first order autocorrelation of the residuals ε_{it} using the Durbin–Watson test statistic [9, 10], which compares the ordinary least squares (OLS) residual for period t with the residual from the preceding period $t - 1$, and is defined as:

$$d = \frac{\sum_{t=2}^{T} (\hat{\varepsilon}_t - \hat{\varepsilon}_{t-1})^2}{\sum_{t=1}^{T} \hat{\varepsilon}_t^2}. \tag{4}$$

The Durbin–Watson test statistic can vary between 0 and 4. If the Durbin–Watson test statistic equals 2, there is absolutely no first order autocorrelation. A d value significantly less (greater) than 2 indicates a positive (negative) autocorrelation. Corresponding tables for different sample sizes can be found in Durbin and Watson [10] and Savin and White [24]. Applying the Durbin–Watson test, we found first order autocorrelation in nearly all of the time series in the sample. As a consequence, OLS test statistics are no longer valid because standard errors are biased and, therefore, causing serious misleading signals [11, 30]. In order to take autocorrelation into account, we employ iterated Prais–Winsten [23] estimation. Accordingly, we found that the trend coefficients, which are statistically significant according to the Prais–Winsten estimation, do not differ greatly from the OLS estimates. This does not hold for the Cochrane–Orcutt estimation that we conducted, but which is inferior to the Prais–Winsten iteration, especially in the case of a smaller time series sample size [5, 15, 22]. Therefore, we will only report the Prais–Winsten estimators.

4 Results

4.1 Descriptive statistics

For a brief overview of the firms analyzed, the means, medians, and variation coefficients of the different inventory to sales ratios are given in Table 1. The variation coefficients indicate the relative degree of movements inside a company's or a sector's inventory ratios.

Furthermore, Table 2 shows the means, medians, and variation coefficients for the sample's industry groups according to the SIC codes. Because some SIC code classes consist of less than ten firms, they are not listed here, whereas, the SIC codes 22 and 23 are merged due to their similarity.

To calculate means, medians, and variation coefficients on an industry group level, we first determined the sum of the weighted inventory to sales ratios of all firms within one sector for each year of the time frame investigated. The numbers shown in Table 2 are based on variable aggregation weights; this means that the sales of a company for each year are divided by the sector's total sales of the corresponding year.

4.2 Empirical tests

The results of our time series regression analysis for testing hypothesis 1 are provided in Table 3.[3] Considering hypothesis 1 (a) we find significantly decreasing (increasing) total inventory to sales ratios for 26 (22) firms. Decreasing (increasing) RM inventory to sales ratios are diagnosed for 28 (29) firms [Hypothesis 1 (b)]. 41 (23) firms show a significantly decreasing (increasing) trend in WP inventories [Hypothesis 1 (c)].[4] Finally, decreasing

[2] Hence, there is a deviation from total inventories reported in the balance sheets, which may also contain payments in advance to suppliers, for example.

[3] In order to save space, the intercept parameter estimates obtained are not reported. Only the trend coefficients (slope), together with t-statistics (P value) and coefficients of determination (R^2) are reported.

[4] Six cases are rejections due to a trend coefficient of zero. That is, because some firms do not carry work-in-process inventories (e.g., soft drinks or wearing apparel), whereas in the chemical industry work-in-process and finished goods inventories are usually combined into one balance sheet item due to production conditions.

Table 1 Means, medians, and variation coefficients of inventory ratios 1993–2005 (sample)

No.	SIC	Firm	TI			RM			WP			FG		
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)
1	20	A. Moksel AG	3.79	3.69	16.07	0.42	0.31	41.89	0.02	0.00	165.61	3.35	3.33	14.41
2	20	Actris AG	5.06	5.12	17.24	2.11	2.08	27.12	0.83	0.89	22.65	2.13	2.23	16.84
3	20	ADM Hamburg AG	11.15	11.37	19.64	8.94	9.45	19.95	0.25	0.28	18.74	1.96	2.03	30.49
4	20	Berentzen-Gruppe AG	12.00	11.46	16.76	2.84	2.75	25.75	3.21	3.21	41.25	5.95	5.36	28.33
5	20	Dom Brauerei AG	5.13	4.88	22.54	2.02	1.90	21.71	1.48	1.06	60.80	1.63	1.50	32.52
6	20	Frosta AG	15.64	15.91	9.20	6.42	6.23	26.34	2.54	2.71	37.10	6.68	6.57	9.62
7	20	Kulmbacher Brauerei AG	6.01	5.90	8.63	2.63	2.44	26.52	1.10	1.07	21.11	2.28	2.33	22.91
8	20	Mineralbrunnen AG	4.20	4.22	22.37	2.54	2.31	19.38	0.00	0.00	n. def.	1.66	1.47	31.44
9	20	Südzucker AG	30.61	29.10	15.54	2.31	2.11	20.30	5.48	4.53	43.00	22.82	22.98	10.51
10	20	Sektkellerei Schloss Wachenheim AG	35.80	26.18	46.67	5.91	4.59	47.92	21.11	14.32	56.17	8.77	8.00	46.17
11	20	Staatl. Mineralbrunnen AG	3.28	3.09	20.98	1.23	1.21	26.01	0.00	0.00	n. def.	2.05	2.02	26.60
12	20	VK Muehlen AG	9.83	10.02	17.74	6.91	7.12	20.07	0.23	0.29	59.78	2.68	2.58	23.20
13	22	Bremer Woll-Kämmerei AG	23.96	26.17	29.60	9.62	9.96	31.53	0.19	0.19	34.52	14.14	12.78	35.02
14	22	Gruschwitz Textilwerke AG	22.41	21.45	10.21	6.41	6.30	48.78	8.58	5.91	42.38	7.42	7.50	17.05
15	22	Kunert AG	34.39	35.34	6.04	5.18	4.93	10.06	5.55	5.78	21.99	23.67	24.05	10.54
16	22	Textilgruppe Hof AG	20.31	19.57	18.24	4.71	4.86	16.48	3.94	3.27	44.82	11.67	10.77	36.31
17	22	Vereinigte Filzfabriken AG	14.02	13.02	17.70	4.90	4.87	9.75	2.93	2.99	19.51	6.20	5.36	26.63
18	23	Adidas AG	19.18	20.86	22.09	0.64	0.64	47.47	0.15	0.13	38.57	18.39	20.46	24.10
19	23	Ahlers AG	20.30	20.67	15.37	7.09	7.10	17.48	0.67	0.69	36.17	12.54	12.75	15.77
20	23	Escada AG	18.89	19.61	17.57	3.08	3.11	18.92	2.16	1.84	27.76	13.66	15.22	27.24
21	23	Etienne Aigner AG	14.07	16.81	29.06	1.38	1.23	35.30	0.00	0.00	n. def.	12.69	14.78	30.15
22	23	Gerry Weber International AG	12.56	11.83	23.25	1.88	1.97	27.33	3.96	3.97	39.08	6.72	7.45	26.55
23	23	Hirsch AG	15.55	16.10	20.93	4.63	4.50	19.94	3.18	3.06	12.02	7.74	8.27	32.08
24	23	Hucke AG	10.60	10.91	13.84	5.33	5.61	16.53	1.08	1.44	92.92	4.18	4.05	17.32
25	23	Hugo Boss AG	17.32	16.31	13.29	4.49	4.46	13.88	0.84	0.86	14.27	11.99	11.27	20.15
26	23	Puma AG	18.61	18.80	18.81	0.24	0.13	86.88	3.59	4.28	70.96	14.77	15.14	12.00
27	23	Triumph International AG	24.46	24.21	6.11	4.10	4.12	12.30	3.97	3.99	13.38	16.40	16.82	8.08
28	28	Altana AG	12.73	12.72	8.76	4.14	4.09	9.36	1.93	1.93	13.40	6.66	6.64	12.70
29	28	BASF AG	14.12	14.46	7.78	2.20	2.73	51.22	0.22	0.22	41.17	11.69	11.50	15.28
30	28	Bayer Aktiengesellschaft	20.34	20.53	3.38	3.67	3.51	10.62	0.00	0.00	n. def.	16.68	16.85	3.33
31	28	Beiersdorf AG	13.44	14.02	8.36	3.43	3.35	19.38	1.02	0.98	17.26	8.99	8.45	12.44
32	28	Biotest AG	44.01	45.60	17.28	11.47	10.79	33.48	23.88	23.11	32.46	8.66	8.50	9.02
33	28	Fresenius SE	11.75	9.56	32.35	2.77	2.03	44.64	1.67	1.39	41.34	7.31	6.16	26.31
34	28	Fuchs Petrolub AG	12.97	12.60	6.05	5.38	5.37	6.18	0.62	0.59	11.56	6.97	6.85	8.22
35	28	Henkel KGaA	12.00	12.91	12.75	3.81	4.01	18.09	1.11	1.32	45.64	7.08	7.24	8.76
36	28	Linde AG	17.55	19.03	31.70	2.88	3.01	22.26	8.02	9.38	55.61	6.65	6.54	11.15
37	28	Merck KGaA	19.69	19.44	11.87	4.22	4.30	20.57	0.00	0.00	n. def.	15.48	15.14	10.43
38	28	Süd Chemie AG	17.03	16.88	6.88	6.10	6.00	9.53	3.11	3.01	17.37	7.82	7.98	9.19
39	28	Schering AG	19.56	19.25	11.67	4.08	3.96	12.29	8.00	7.86	13.77	7.48	7.29	12.38
40	30	Continental AG	12.32	11.86	18.79	3.21	3.26	9.36	1.53	1.51	19.18	7.58	7.13	25.65
41	30	Ehlebracht AG	11.88	12.94	28.36	4.64	4.29	25.85	2.13	2.41	45.14	5.12	5.56	37.78
42	30	New York-Hamburger Gummi-Waaren Compagnie AG	17.72	17.97	9.52	4.01	3.91	15.76	6.30	6.21	17.25	7.41	7.56	20.50
43	30	Simona AG	18.71	18.79	8.14	4.88	5.12	14.22	0.00	0.00	n. def.	13.82	13.81	8.67
44	30	WERU AG	6.44	6.38	13.29	5.53	5.43	16.07	0.35	0.33	27.25	0.56	0.54	21.82

Table 1 continued

No.	SIC	Firm	TI			RM			WP			FG		
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)
45	32	BHS tabletop AG	16.75	16.53	23.75	2.94	2.56	33.80	1.53	1.66	48.55	12.28	12.01	21.86
46	32	Didier-Werke AG	16.87	17.32	19.59	5.24	5.44	23.77	3.52	3.23	34.60	8.11	6.96	29.88
47	32	Dyckerhoff AG	9.93	10.01	9.66	4.34	3.99	13.77	1.56	1.41	27.13	4.03	4.10	24.46
48	32	Erlus AG	9.19	10.01	41.32	1.52	1.65	30.41	0.30	0.31	16.92	7.36	7.85	45.61
49	32	Heidelbergcement AG	10.27	10.25	5.79	5.26	5.28	9.45	1.32	1.27	20.92	3.69	3.53	12.78
50	32	Keramag AG	10.07	10.19	8.82	0.72	0.61	34.31	0.54	0.38	51.87	8.82	8.86	8.52
51	32	Pilkington Deutschland AG	7.48	7.86	22.68	1.86	1.68	31.13	0.39	0.21	90.13	5.24	5.33	22.67
52	32	Rosenthal AG	29.22	27.77	16.24	2.62	2.66	16.31	6.08	5.20	70.23	20.52	21.03	16.43
53	32	Saint Gobain Oberland AG	13.76	13.17	21.84	3.59	3.08	52.32	0.38	0.22	97.38	9.79	9.64	11.60
54	32	SGL Carbon AG	27.57	26.78	9.32	7.22	7.10	12.37	14.66	14.46	9.05	5.68	5.64	13.66
55	32	Sto AG	7.76	7.79	6.50	2.00	1.95	8.57	0.18	0.16	32.00	5.59	5.58	7.81
56	32	Teutonia Zementwerk AG	16.49	15.59	17.60	8.73	8.48	19.37	4.87	4.26	34.37	2.89	2.51	35.47
57	32	Villeroy and Boch AG	26.19	25.95	7.20	3.75	3.75	6.50	4.02	3.56	16.85	18.42	18.20	9.61
58	33	Norddeutsche Affinerie AG	15.89	16.20	14.41	5.82	5.80	13.61	6.31	6.03	21.50	3.76	3.77	32.01
59	34	Innotec TSS AG	14.39	14.66	13.96	6.04	6.21	18.62	6.12	5.87	37.72	2.23	2.32	36.60
60	34	Salzgitter AG	16.82	16.25	9.81	4.43	4.22	25.44	3.47	3.77	22.89	8.92	9.04	7.13
61	34	WMF AG	25.06	25.00	8.31	3.58	3.61	11.06	2.82	2.80	8.79	18.66	18.79	9.61
62	35	Alexanderwerk AG	37.82	37.18	30.69	3.78	4.01	31.50	25.52	23.72	47.27	8.52	6.57	65.12
63	35	Bertold Hermle AG	18.32	17.15	25.43	3.27	3.29	67.97	8.80	5.56	56.15	6.25	6.60	31.04
64	35	Deutz AG	32.44	26.71	44.24	11.13	11.35	13.62	15.69	10.05	84.28	5.62	5.40	21.55
65	35	Dürkopp Adler AG	28.70	28.51	8.89	7.22	7.01	25.82	9.09	9.14	13.28	12.39	12.36	18.99
66	35	Dürr AG	15.25	15.03	72.70	2.23	2.16	16.37	12.86	12.03	89.27	0.16	0.05	90.25
67	35	GEA Group AG	10.62	10.32	18.17	2.13	2.46	29.64	4.74	4.51	30.34	3.75	3.93	16.13
68	35	Gildemeister AG	29.52	26.16	33.74	10.10	8.80	34.76	11.69	8.31	66.41	7.72	7.84	25.38
69	35	Jagenberg AG	19.34	21.00	25.92	4.48	4.02	20.86	12.18	13.50	26.93	2.68	2.77	57.44
70	35	Junghenrich AG	11.36	10.19	20.50	5.41	4.69	24.30	1.79	1.91	52.49	4.15	4.18	13.63
71	35	Kloeckner-Werke AG	18.10	15.57	37.52	6.33	5.53	31.06	9.58	7.74	54.91	2.19	2.01	28.94
72	35	Koenig and Bauer AG	34.08	36.71	16.60	6.37	6.23	32.46	27.48	28.33	15.19	0.23	0.14	93.12
73	35	Krones AG	12.74	11.92	27.93	3.44	3.12	37.08	5.70	5.62	20.58	3.60	3.37	40.63
74	35	KSB AG	19.60	20.36	13.41	6.07	5.92	8.21	8.38	8.67	27.00	5.16	5.26	12.14
75	35	KUKA AG	26.87	27.20	22.05	5.75	5.87	10.69	18.73	19.19	28.53	2.40	2.24	17.79
76	35	Rheinmetall AG	20.28	20.29	18.76	5.40	4.83	21.80	10.94	11.53	32.57	3.94	3.41	23.80
77	35	Sartorius AG	18.29	18.39	15.19	3.83	3.83	14.02	5.47	5.75	15.72	8.99	8.70	22.80
78	35	Triumph Adler AG	15.97	15.82	28.00	1.71	1.90	61.98	2.55	1.64	103.03	11.70	12.52	35.11
79	35	Vossloh AG	21.40	18.16	28.43	7.64	7.89	29.76	8.00	6.96	54.91	5.76	6.64	49.07
80	36	Brilliant AG	22.83	23.02	10.35	6.44	7.38	57.35	1.89	1.87	64.04	14.51	13.43	23.68
81	36	Ceag AG	20.28	21.02	19.51	6.60	6.72	17.96	3.70	3.45	59.15	9.98	10.13	27.54
82	36	Leifheit AG	15.60	15.20	13.21	4.02	3.66	28.17	1.85	1.65	37.33	9.73	8.95	23.49
83	36	M.tech AG	20.15	18.58	28.14	5.17	5.02	18.02	14.52	12.20	35.28	0.46	0.00	115.87
84	36	Schweizer Electronic AG	11.26	11.40	8.38	4.68	4.42	16.01	3.61	3.61	15.13	2.97	2.96	36.56
85	36	Sedlbauer AG	15.98	14.59	21.55	8.61	7.40	30.69	4.60	4.35	18.01	2.77	2.51	27.25
86	36	Vogt Electronic AG	17.82	17.18	22.43	8.77	8.76	19.55	4.39	3.62	38.74	4.66	3.62	50.76
87	37	Audi AG	6.31	5.94	16.88	1.36	1.38	19.64	1.42	1.45	16.87	3.54	3.44	32.96
88	37	BBS Fahrzeugtechnik AG	22.10	21.96	14.04	5.22	4.91	22.16	5.76	5.54	20.05	11.12	11.53	21.18
89	37	BMW AG	12.06	12.07	12.49	1.36	1.37	10.43	1.75	1.77	16.01	8.95	9.09	14.33
90	37	Hymer AG	21.75	20.35	15.26	8.94	8.99	19.74	1.75	1.76	15.52	11.06	10.05	18.73

Table 1 continued

No.	SIC	Firm	TI			RM			WP			FG		
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)
91	37	MAN AG	37.18	36.60	13.46	3.76	3.71	7.89	18.76	18.39	18.85	14.66	16.34	39.41
92	37	Porsche AG	11.01	10.86	16.57	1.46	1.21	50.90	3.41	3.39	43.21	6.15	6.65	23.74
93	37	Progress-Werke Oberkirch AG	14.44	14.15	16.88	5.20	4.78	27.74	6.29	6.14	31.43	2.95	3.06	15.41
94	37	Schaltbau Holding AG	25.10	25.89	20.00	9.00	8.45	14.93	12.08	11.30	31.65	4.01	3.74	28.18
95	37	Veritas AG	9.84	9.48	16.48	3.57	3.30	25.12	2.64	2.45	46.89	3.63	3.56	21.25
96	37	Volkswagen AG	11.37	10.83	13.21	2.24	2.22	7.01	1.67	1.45	19.14	7.47	7.33	20.52
97	37	Wanderer-Werke AG	22.62	23.79	12.48	4.61	3.85	29.63	6.53	6.58	13.79	11.48	11.96	19.45
98	38	Draegerwerk AG	21.91	23.28	17.76	5.30	5.68	19.86	6.70	7.22	32.15	9.92	10.36	16.77
99	38	Siemens AG	15.01	14.07	17.82	2.98	2.96	9.86	7.27	5.23	44.05	4.76	4.67	16.21
100	39	Johann F. Behrens AG	26.47	26.29	6.97	6.54	5.91	26.18	1.90	2.21	75.73	18.03	18.12	8.33

Table 2 Means, medians, and variation coefficients of inventory ratios 1993–2005 (SIC code classes)

SIC	TI			RM			WP			FG		
	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)
20	18.41	18.39	13.74	3.24	3.27	7.59	3.06	2.79	40.01	12.12	12.23	9.67
22/23	18.90	19.48	11.84	2.51	2.32	30.57	1.34	1.28	22.27	15.05	14.39	11.84
28	16.20	16.25	6.87	3.16	3.04	8.72	1.26	1.32	21.29	11.78	11.49	8.66
32	13.71	13.43	4.30	4.65	4.48	8.75	2.79	2.77	7.56	6.28	6.27	10.13
35	17.21	16.82	11.03	4.53	4.68	10.45	8.77	9.01	21.45	3.90	3.81	7.32
37	13.57	13.63	6.41	2.11	2.05	6.77	3.43	3.17	20.13	8.03	7.84	14.47
Total	15.08	15.32	3.65	2.91	2.90	3.34	3.82	3.83	8.90	8.36	8.40	3.61

(increasing) FGs inventories are significant for 24 (22) firms [Hypothesis 1 (d)].

On an aggregated level, the results of our time series regression analysis for testing hypothesis 2 are provided in Table 4. Considering hypothesis 2 (a), total inventory to sales ratios decrease (increase) to a significant extent in four (one) sector(s). Decreasing (increasing) RM inventory to sales ratios can be observed in one (two) industry sector(s) [Hypothesis 2 (b)], while three sectors show a significantly constant trend with a slope of 0. Regarding WP inventories [Hypothesis 2 (c)], the regression analysis results in four (one) sector(s) with a significantly decreasing (increasing) behavior. Decreasing (increasing) FGs inventories are significant for two (one) industries [Hypothesis 2 (d)].

To answer the question at which stages inventory reduction mainly has taken place, we proceed with testing hypothesis 3, comparing the trend coefficients of different inventory stages between 1993 and 2005 for each firm (see Table 5).

A negative value in the WP versus RMs (FGs) column indicates that WP inventories performed better [i.e., show a higher (lower) decreasing (increasing) trend] when compared to RMs (FGs) and a negative value in the RMs versus FGs column indicates that RMs inventories performed better when compared to FGs. Considering Hypothesis 3 (a), WP inventory ratios compared to RM inventory ratios performed significantly better (worse) in 42 (17) firms. In 34 (25) cases, a significantly better (worse) development of the WP inventory ratio can be noticed [Hypothesis 3 (b)] when compared to the corresponding FGs inventory ratio. RMs inventory ratios showed a better (worse) performance for 26 (28) firms [Hypothesis 3 (c)] when compared to FGs inventory ratios. On an aggregated level, the results of our time series regression analysis for testing hypothesis 4 are provided in Table 6, comparing the trend coefficients of different inventory stages between 1993 and 2005 for each SIC class.

Testing hypothesis 4 (a) WP inventory ratios performed better (worse) in four (two) sectors when compared to RM

Table 3 Overall trend coefficients 1993–2005

No.	SC	Firm	TI			RM			WP			FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2	β	P value	R^2
1	20	A. Moksel AG	−0.056	0.400	0.072	−0.017	0.332	0.094	0.004*	0.091	0.259	−0.045	0.404	0.071
2	20	Actris AG	−0.022	0.798	0.007	0.033	0.570	0.033	−0.033**	0.046	0.341	−0.020	0.484	0.050
3	20	ADM Hamburg AG	−0.144	0.545	0.038	−0.080	0.683	0.017	−0.002	0.500	0.047	−0.069	0.194	0.162
4	20	Berentzen-Gruppe AG	0.322*	0.084	0.270	0.152***	0.000	0.730	−0.205	0.187	0.167	0.364***	0.002	0.625
5	20	Dom Brauerei AG	0.183***	0.004	0.579	−0.053	0.207	0.154	0.080	0.328	0.096	0.108***	0.001	0.666
6	20	Frosta AG	−0.166	0.156	0.190	−0.292**	0.040	0.358	0.240***	0.000	0.785	−0.068	0.190	0.165
7	20	Kulmbacher Brauerei AG	0.049	0.241	0.134	0.061	0.285	0.113	−0.039**	0.039	0.361	0.035	0.384	0.076
8	20	Mineralbrunnen AG	0.217***	0.001	0.694	0.097***	0.004	0.575	0.000***	0.000	0.000	0.120***	0.000	0.743
9	20	Südzucker AG	0.775	0.133	0.211	0.108**	0.013	0.473	0.516**	0.018	0.443	0.138	0.630	0.024
10	20	Sektkellerei Schloss Wachenheim AG	−3.583***	0.002	0.646	−0.485**	0.019	0.438	−2.576***	0.002	0.650	−0.469	0.133	0.211
11	20	Saatl. Mineralbrunnen AG	0.155***	0.001	0.696	0.030	0.390	0.075	0.000***	0.000	0.000	0.128***	0.000	0.856
12	20	VK Muehlen AG	0.280**	0.038	0.363	0.221**	0.041	0.354	0.018*	0.095	0.253	0.041	0.553	0.036
13	22	Bremer Woll-Kämmerei AG	−1.515***	0.003	0.597	−0.624***	0.008	0.526	−0.013***	0.001	0.713	−0.867**	0.031	0.387
14	22	Gruschwitz Textilwerke AG	−0.026	0.908	0.001	0.631***	0.001	0.688	−0.635**	0.036	0.371	0.023	0.837	0.004
15	22	Kunert AG	−0.026	0.849	0.004	−0.087*	0.051	0.329	−0.312***	0.000	0.850	0.369**	0.022	0.424
16	22	Textilgruppe Hof AG	0.715**	0.018	0.442	0.087	0.189	0.166	−0.395***	0.002	0.648	1.016***	0.000	0.769
17	22	Verenigte Filzfabriken AG	0.528***	0.003	0.596	0.087***	0.005	0.554	0.106***	0.009	0.512	0.348***	0.005	0.568
18	23	Adidas AG	−0.932***	0.000	0.725	0.030	0.275	0.118	0.004	0.573	0.033	−0.976***	0.001	0.702
19	23	Ahlers AG	−0.574**	0.018	0.442	−0.212**	0.040	0.356	−0.032	0.267	0.121	−0.376***	0.009	0.509
20	23	Escada AG	0.629*	0.051	0.329	−0.058	0.339	0.092	−0.110**	0.024	0.415	0.753**	0.017	0.449
21	23	Etienne Aigner AG	0.886***	0.007	0.531	0.092**	0.047	0.340	0.000***	0.000	0.000	0.793**	0.011	0.494
22	23	Gerry Weber International AG	−0.048	0.894	0.002	−0.084*	0.088	0.263	−0.151	0.394	0.074	0.244	0.119	0.226
23	23	Hirsch AG	0.460	0.209	0.153	0.034	0.737	0.012	0.011	0.764	0.009	0.379	0.114	0.230
24	23	Hucke AG	−0.151	0.280	0.115	−0.171***	0.001	0.655	0.009	0.938	0.001	−0.006	0.929	0.001
25	23	Hugo Boss AG	0.497**	0.012	0.487	−0.097*	0.064	0.303	0.004	0.702	0.015	0.589***	0.000	0.749
26	23	Puma AG	0.148	0.724	0.013	−0.052***	0.001	0.716	0.429*	0.077	0.280	−0.189	0.343	0.090
27	23	Triumph International AG	0.097	0.580	0.032	−0.097***	0.006	0.544	−0.013	0.782	0.008	0.212	0.103	0.243
28	28	Altana AG	−0.166*	0.088	0.263	−0.076***	0.009	0.509	0.021	0.284	0.114	−0.101	0.236	0.137
29	28	BASF AG	−0.212**	0.037	0.366	0.207**	0.042	0.353	−0.016*	0.076	0.281	−0.415***	0.001	0.678
30	28	Bayer Aktiengesellschaft	0.067	0.109	0.236	0.049*	0.093	0.256	0.000***	0.000	0.000	0.014	0.662	0.020
31	28	Beiersdorf AG	−0.135	0.339	0.092	−0.174***	0.000	0.904	−0.041***	0.008	0.519	0.076	0.546	0.038
32	28	Biotest AG	1.600***	0.004	0.585	−0.252	0.564	0.034	1.848***	0.000	0.796	0.025	0.782	0.008
33	28	Fresenius SE	−0.777**	0.018	0.442	−0.249**	0.022	0.425	−0.118*	0.080	0.275	−0.412***	0.008	0.524
34	28	Fuchs Petrolub AG	0.092	0.307	0.104	−0.008	0.795	0.007	0.015***	0.009	0.514	0.067	0.301	0.106

Table 3 continued

No.	SC	Firm	TI			RM			WP			FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2	β	P value	R^2
35	28	Henkel KGaA	−0.254**	0.027	0.402	−0.154***	0.001	0.710	−0.107***	0.005	0.559	0.012	0.806	0.006
36	28	Linde AG	−1.304***	0.001	0.652	−0.129***	0.006	0.543	−0.992***	0.003	0.591	−0.154**	0.010	0.498
37	28	Merck KGaA	−0.444**	0.018	0.444	−0.116	0.172	0.178	0.000***	0.000	0.000	−0.325***	0.007	0.536
38	28	Süd Chemie AG	−0.041	0.734	0.012	−0.004	0.958	0.000	0.051	0.368	0.082	−0.099*	0.051	0.329
39	28	Schering AG	−0.459*	0.096	0.253	−0.091	0.109	0.236	−0.172	0.263	0.123	−0.168**	0.025	0.410
40	30	Continental AG	−0.568***	0.000	0.856	−0.012	0.605	0.028	−0.068***	0.000	0.804	−0.488***	0.000	0.896
41	30	Ehlebracht AG	−0.410	0.255	0.127	−0.232**	0.024	0.415	0.039	0.775	0.009	−0.215	0.314	0.101
42	30	New York-Hamburger Gummi-Waaren Compagnie AG	−0.025	0.891	0.002	0.033	0.558	0.035	0.162	0.101	0.246	−0.230	0.159	0.188
43	30	Simona AG	0.132	0.348	0.088	0.114**	0.043	0.349	0.000***	0.000	0.000	0.021	0.851	0.004
44	30	WERU AG	0.177***	0.000	0.814	0.190***	0.000	0.786	−0.004	0.605	0.028	−0.007	0.249	0.130
45	32	BHS tabletop AG	0.572	0.161	0.187	0.191**	0.030	0.390	−0.043	0.639	0.023	0.426*	0.089	0.262
46	32	Didier-Werke AG	−0.296	0.269	0.120	−0.104	0.374	0.080	0.177	0.127	0.217	−0.392**	0.024	0.413
47	32	Dyckerhoff AG	0.057	0.411	0.069	0.106**	0.015	0.463	0.065*	0.075	0.283	−0.125	0.218	0.147
48	32	Erlus AG	0.866***	0.007	0.533	0.107***	0.000	0.786	0.009**	0.031	0.386	0.744**	0.012	0.486
49	32	Heidelbergcement AG	0.041	0.411	0.069	0.061	0.357	0.085	−0.040*	0.053	0.325	0.023	0.666	0.019
50	32	Keramag AG	0.150**	0.016	0.459	0.051***	0.006	0.541	0.051*	0.064	0.302	0.049	0.375	0.079
51	32	Pilkington Deutschland AG	−0.135	0.495	0.048	−0.122***	0.009	0.515	−0.071***	0.010	0.504	0.051	0.721	0.013
52	32	Rosenthal AG	0.690*	0.094	0.255	−0.055	0.149	0.196	0.711**	0.042	0.353	−0.195	0.578	0.032
53	32	Saint Gobain Oberland AG	0.275	0.327	0.096	0.242	0.180	0.172	0.046	0.248	0.131	−0.020	0.833	0.005
54	32	SGL Carbon AG	0.042	0.878	0.002	0.137*	0.088	0.263	−0.084	0.462	0.055	−0.002	0.979	0.000
55	32	Sto AG	−0.052	0.354	0.086	0.005	0.727	0.013	0.004	0.541	0.038	−0.050	0.223	0.145
56	32	Teutonia Zementwerk AG	0.395***	0.000	0.719	0.308***	0.005	0.570	0.180**	0.035	0.374	−0.090	0.385	0.076
57	32	Villeroy and Boch AG	−0.269	0.186	0.168	−0.010	0.703	0.015	−0.135**	0.011	0.489	−0.111	0.619	0.026
58	33	Norddeutsche Affinerie AG	−0.319**	0.045	0.343	0.051	0.350	0.088	−0.109	0.259	0.125	−0.261***	0.000	0.758
59	34	Innotec TSS AG	0.099	0.594	0.029	0.247***	0.002	0.634	−0.360	0.175	0.176	0.095	0.237	0.137
60	34	Salzgitter AG	0.398***	0.000	0.774	0.279***	0.000	0.795	0.172***	0.002	0.650	−0.060	0.210	0.152
61	34	WMF AG	0.005	0.981	0.000	0.071***	0.007	0.539	−0.006	0.805	0.006	−0.060	0.734	0.012
62	35	Alexanderwerk AG	−0.535	0.540	0.039	−0.030	0.810	0.006	−1.490	0.154	0.192	0.653	0.238	0.136
63	35	Bertold Hermle AG	−0.741	0.146	0.199	0.554***	0.000	0.878	−1.128***	0.002	0.642	−0.150	0.509	0.045
64	35	Deutz AG	−3.061***	0.002	0.644	−0.233*	0.090	0.260	−2.530**	0.011	0.489	−0.232*	0.058	0.313
65	35	Dürkopp Adler AG	−0.156	0.467	0.054	0.454***	0.000	0.898	−0.243***	0.003	0.614	−0.390*	0.057	0.316
66	35	Dürr AG	−2.430***	0.001	0.660	0.060*	0.098	0.250	−2.503***	0.002	0.649	0.032***	0.001	0.695
67	35	GEA Group AG	−0.090	0.564	0.034	0.082	0.174	0.176	−0.159	0.205	0.155	−0.029	0.540	0.039
68	35	Gildemeister AG	−1.777*	0.062	0.306	−0.638**	0.035	0.373	−1.525*	0.059	0.313	0.336**	0.035	0.372

Table 3 continued

No.	SC	Firm	TI			RM			WP			FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2	β	P value	R^2
69	35	Jagenberg AG	−0.986***	0.002	0.619	−0.039	0.610	0.027	−0.737***	0.000	0.807	−0.222*	0.097	0.252
70	35	Jungheinrich AG	−0.464***	0.002	0.636	−0.284***	0.001	0.689	−0.223***	0.000	0.811	0.056	0.199	0.159
71	35	Kloeckner-Werke AG	1.193**	0.022	0.421	0.359**	0.044	0.347	0.862**	0.029	0.395	−0.025	0.612	0.027
72	35	Koenig and Bauer AG	−1.273***	0.001	0.658	−0.443***	0.005	0.563	−0.815**	0.016	0.454	−0.011	0.680	0.018
73	35	Krones AG	0.542*	0.100	0.248	0.268***	0.009	0.510	0.049	0.661	0.020	0.244*	0.054	0.324
74	35	KSB AG	−0.530***	0.006	0.547	0.077**	0.042	0.351	−0.545***	0.000	0.819	−0.060	0.388	0.075
75	35	KUKA AG	−1.174***	0.006	0.549	−0.110*	0.050	0.332	−1.025***	0.006	0.545	−0.053	0.154	0.192
76	35	Rheinmetall AG	−0.787**	0.030	0.391	0.131	0.305	0.104	−0.893***	0.000	0.844	0.013	0.917	0.001
77	35	Sartorius AG	−0.594**	0.011	0.491	0.075	0.167	0.182	−0.203***	0.000	0.763	−0.457***	0.005	0.568
78	35	Triumph Adler AG	0.654	0.259	0.125	−0.231***	0.009	0.515	−0.292	0.321	0.098	0.937***	0.002	0.647
79	35	Vossloh AG	0.244	0.725	0.013	0.311	0.148	0.197	0.556	0.209	0.153	−0.631***	0.000	0.719
80	36	Brilliant AG	−0.224	0.128	0.216	−0.679*	0.058	0.314	−0.255*	0.061	0.308	0.619**	0.030	0.391
81	36	Ceag AG	−0.146	0.728	0.013	−0.037	0.743	0.011	−0.476***	0.002	0.633	0.347	0.232	0.139
82	36	Leifheit AG	0.002	0.993	0.000	−0.311***	0.004	0.579	−0.176***	0.000	0.965	0.447**	0.023	0.420
83	36	M.tech AG	−0.326	0.483	0.050	−0.081	0.308	0.103	−0.384	0.378	0.078	0.121***	0.001	0.708
84	36	Schweizer Electronic AG	0.143*	0.070	0.292	0.026	0.692	0.016	−0.044	0.463	0.055	0.153*	0.094	0.255
85	36	Sedlbauer AG	−0.337	0.311	0.102	−0.128	0.600	0.028	−0.079	0.242	0.134	−0.153***	0.001	0.669
86	36	Vogt Eectronic AG	−0.878***	0.000	0.776	−0.015	0.894	0.002	−0.398***	0.000	0.767	−0.496**	0.013	0.477
87	37	Audi AG	0.247***	0.000	0.752	0.046*	0.071	0.289	−0.043*	0.061	0.307	0.228**	0.012	0.484
88	37	BBS Fahrzeugtechnik AG	−0.453*	0.099	0.249	−0.055	0.577	0.032	−0.002	0.980	0.000	−0.409*	0.062	0.307
89	37	BMW AG	0.194	0.214	0.150	−0.004	0.778	0.008	0.031	0.276	0.117	0.167	0.207	0.154
90	37	Hymer AG	−0.247	0.468	0.054	0.075	0.661	0.020	−0.054***	0.001	0.685	−0.300*	0.066	0.299
91	37	MAN AG	0.336	0.525	0.042	−0.044*	0.092	0.258	−0.721***	0.007	0.528	1.048**	0.046	0.342
92	37	Porsche AG	−0.079	0.673	0.019	−0.156**	0.027	0.400	−0.103	0.485	0.050	0.172	0.255	0.127
93	37	Progress-Werke Oberkirch AG	0.168	0.571	0.033	−0.233*	0.064	0.303	0.344*	0.072	0.288	0.028	0.616	0.026
94	37	Schaltbau Holding AG	−0.641	0.155	0.191	−0.067	0.490	0.049	−0.335	0.420	0.066	−0.239***	0.003	0.592
95	37	Veritas AG	−0.093	0.613	0.026	0.168**	0.029	0.395	−0.185**	0.033	0.380	−0.021	0.793	0.007
96	37	Volkswagen AG	−0.026	0.897	0.002	−0.017	0.298	0.107	−0.067**	0.010	0.497	0.039	0.843	0.004
97	37	Wanderer-Werke AG	−0.399	0.114	0.230	−0.180	0.178	0.173	−0.122*	0.082	0.272	0.062	0.837	0.004
98	38	Draegerwerk AG	−0.936***	0.000	0.823	−0.071	0.526	0.041	−0.459***	0.004	0.589	−0.409***	0.000	0.773
99	38	Siemens AG	0.474**	0.046	0.342	−0.013	0.631	0.024	0.682***	0.005	0.560	−0.199***	0.000	0.930
100	39	Johann F. Behrens AG	0.120	0.580	0.032	0.394***	0.002	0.632	−0.275**	0.015	0.464	−0.007	0.970	0.000

t statistic (*$P < 0.1$, **$P < 0.05$, ***$P < 0.01$)

Table 4 Overall trend coefficients for SIC classes 1993–2005

SC	TI			RM			WP			FG		
	β	P value	R^2	β	P value	R^2	β	P value	R^2	β	P value	R^2
20	0.606***	0.001	0.679	0.044***	0.006	0.542	0.301***	0.001	0.671	0.262***	0.004	0.576
22/23	−0.439***	0.006	0.544	−0.194***	0.000	0.885	−0.067**	0.011	0.494	−0.170	0.313	0.101
28	−0.272***	0.000	0.904	−0.011***	0.000	0.955	−0.055***	0.007	0.535	−0.253***	0.000	0.840
32	−0.093**	0.010	0.497	0.089**	0.018	0.445	−0.027	0.106	0.240	−0.144***	0.000	0.887
35	−0.275*	0.095	0.254	0.086**	0.033	0.379	−0.347**	0.019	0.437	−0.014	0.591	0.030
37	−0.026	0.815	0.006	−0.023*	0.098	0.250	−0.173***	0.000	0.849	0.150	0.201	0.158

t statistic (*$P < 0.1$, **$P < 0.05$, ***$P < 0.01$)

Table 5 Difference in regression coefficients 1993–2005 between inventory stages

Nr.	SIC	Firm	WP vs. RM			WP vs. FG			RM vs. FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2
1	20	A. Moksel AG	0.020	0.246	0.132	0.047	0.378	0.078	0.029	0.497	0.047
2	20	Actris AG	−0.068	0.287	0.112	−0.017	0.612	0.027	0.053	0.140	0.205
3	20	ADM Hamburg AG	0.079	0.683	0.017	0.068	0.196	0.161	−0.012	0.939	0.001
4	20	Berentzen-Gruppe AG	−0.383**	0.045	0.344	−0.532***	0.008	0.527	−0.199*	0.054	0.324
5	20	Dom Brauerei AG	0.077	0.526	0.041	−0.069	0.520	0.043	−0.159***	0.009	0.511
6	20	Frosta AG	0.530***	0.004	0.587	0.304***	0.000	0.811	−0.193	0.258	0.126
7	20	Kulmbacher Brauerei AG	−0.100*	0.056	0.317	−0.068	0.199	0.159	0.026	0.778	0.008
8	20	Mineralbrunnen AG	−0.097***	0.004	0.575	−0.120***	0.000	0.743	−0.019	0.396	0.073
9	20	Sektkellerei Schloss Wachenheim AG	−2.065***	0.007	0.537	−2.080***	0.004	0.571	−0.015	0.909	0.001
10	20	Staatl. Mineralbrunnen AG	−0.030	0.390	0.075	−0.128***	0.000	0.856	−0.093**	0.033	0.379
11	20	Süd Zucker AG	0.407**	0.022	0.423	0.368**	0.040	0.359	−0.029	0.910	0.001
12	20	VK Muehlen AG	−0.202*	0.060	0.311	−0.027	0.725	0.013	0.168	0.156	0.191
13	22	Bremer Woll-Kämmerei AG	0.609***	0.010	0.506	0.853**	0.033	0.379	0.236	0.557	0.036
14	22	Gruschwitz Textilwerke AG	−1.245***	0.001	0.652	−0.655	0.117	0.227	0.595***	0.010	0.504
15	22	Kunert AG	−0.244**	0.014	0.472	−0.656***	0.000	0.734	−0.478**	0.014	0.467
16	22	Textilgruppe Hof AG	−0.482***	0.002	0.643	−1.399***	0.000	0.933	−0.926***	0.001	0.688
17	22	Vereinigte Filzfabriken AG	0.021	0.549	0.037	−0.258***	0.002	0.644	−0.288***	0.009	0.508
18	23	Adidas AG	−0.032	0.182	0.171	0.981***	0.001	0.699	1.011***	0.001	0.675
19	23	Ahlers AG	0.181	0.101	0.246	0.354**	0.011	0.496	0.168*	0.051	0.330
20	23	Escada AG	−0.040	0.669	0.019	−0.825**	0.020	0.434	−0.809***	0.003	0.594
21	23	Etienne Aigner AG	−0.092**	0.047	0.340	−0.793**	0.011	0.494	−0.703**	0.018	0.442
22	23	Gerry Weber International AG	−0.072	0.585	0.031	−0.484***	0.000	0.841	−0.351**	0.012	0.484
23	23	Hirsch AG	−0.011	0.877	0.003	−0.356*	0.087	0.264	−0.351**	0.047	0.339
24	23	Hucke AG	0.183	0.203	0.157	0.014	0.911	0.001	−0.154*	0.079	0.276
25	23	Hugo Boss AG	0.101**	0.045	0.343	−0.590***	0.000	0.773	−0.693***	0.000	0.928
26	23	Puma AG	0.478*	0.057	0.316	0.609***	0.000	0.906	0.140	0.487	0.050
27	23	Triumph International AG	0.094**	0.016	0.456	−0.229**	0.041	0.354	−0.303**	0.018	0.444
28	28	Altana AG	0.098***	0.008	0.521	0.120	0.193	0.163	0.036	0.640	0.023
29	28	BASF AG	−0.222**	0.042	0.351	0.399***	0.001	0.686	0.630***	0.002	0.626
30	28	Bayer AG	−0.049*	0.093	0.256	−0.014	0.662	0.020	0.039	0.367	0.082
31	28	Beiersdorf AG	0.135***	0.000	0.965	−0.120	0.325	0.097	−0.241*	0.067	0.297
32	28	Biotest AG	2.048***	0.005	0.559	1.755***	0.000	0.736	−0.290	0.513	0.044
33	28	Fresenius SE	0.133***	0.002	0.623	0.288***	0.002	0.652	0.152***	0.003	0.613

Table 5 continued

Nr.	SIC	Firm	WP vs. RM			WP vs. FG			RM vs. FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2
34	28	Fuchs Petrolub AG	0.026	0.367	0.082	−0.050	0.418	0.067	−0.055	0.365	0.083
35	28	Henkel KGaA	0.038	0.169	0.181	−0.125***	0.001	0.670	−0.167***	0.000	0.784
36	28	Linde AG	−0.846***	0.009	0.509	−0.825***	0.006	0.553	0.009	0.784	0.008
37	28	Merck KGaA	0.116	0.172	0.178	0.325***	0.007	0.536	0.180**	0.036	0.370
38	28	Schering AG	−0.051	0.579	0.032	0.083	0.424	0.065	0.099**	0.030	0.389
39	28	Süd Chemie AG	0.052	0.489	0.049	0.157**	0.032	0.382	0.100	0.238	0.136
40	30	Continental AG	−0.056***	0.008	0.520	0.420***	0.000	0.890	0.476***	0.000	0.909
41	30	Ehlebracht AG	0.228	0.179	0.172	0.274**	0.010	0.497	0.026	0.898	0.002
42	30	New York-Hamburger Gummi-Waaren Compagnie AG	0.174***	0.008	0.519	0.390*	0.064	0.302	0.238	0.200	0.158
43	30	SIMONA AG	−0.114**	0.043	0.349	−0.021	0.851	0.004	0.086	0.431	0.063
44	30	WERU AG	−0.195***	0.000	0.726	0.002	0.824	0.005	0.197***	0.000	0.796
45	32	BHS tabletop AG	−0.229***	0.002	0.640	−0.485***	0.009	0.514	−0.222	0.200	0.158
46	32	Didier-Werke AG	0.287**	0.048	0.337	0.582**	0.011	0.491	0.285*	0.067	0.297
47	32	Dyckerhoff AG	−0.029*	0.081	0.274	0.170	0.211	0.151	0.200	0.146	0.199
48	32	Erlus AG	−0.097***	0.000	0.762	−0.734**	0.012	0.484	−0.630**	0.021	0.428
49	32	Heidelbergcement AG	−0.115*	0.076	0.282	−0.074	0.217	0.148	0.066	0.574	0.033
50	32	Keramag AG	−0.001	0.951	0.000	0.003	0.967	0.000	0.004	0.954	0.000
51	32	Pilkington Deutschland AG	0.050**	0.037	0.365	−0.118	0.364	0.083	−0.171	0.135	0.209
52	32	Rosenthal AG	0.732*	0.052	0.326	1.064*	0.051	0.330	0.140	0.682	0.017
53	32	Saint Gobain Oberland AG	−0.180	0.226	0.143	0.067	0.470	0.053	0.234*	0.084	0.270
54	32	SGL CARBON AG	−0.204***	0.005	0.557	−0.046	0.341	0.091	0.153***	0.006	0.545
55	32	Sto AG	0.001	0.949	0.000	0.054	0.144	0.201	0.049	0.183	0.170
56	32	Teutonia Zementwerk AG	−0.123	0.181	0.172	0.276*	0.096	0.253	0.350*	0.091	0.259
57	32	Villeroy and Boch AG	−0.114*	0.087	0.265	−0.024	0.921	0.001	0.086	0.715	0.014
58	33	Norddeutsch Affinerie AG	−0.159*	0.090	0.260	0.150	0.163	0.185	0.314***	0.000	0.759
59	34	Innotec TSS AG	−0.645**	0.036	0.370	−0.490	0.151	0.194	0.161*	0.094	0.254
60	34	Salzgitter AG	−0.112*	0.088	0.263	0.232**	0.011	0.488	0.340***	0.000	0.805
61	34	WMF AG	−0.089**	0.032	0.381	0.049	0.770	0.009	0.138	0.420	0.066
62	35	Alexanderwerk AG	−1.500	0.178	0.174	−2.281	0.109	0.236	−0.710	0.146	0.199
63	35	Bertold Hermle AG	−1.690***	0.000	0.800	−1.043***	0.000	0.875	0.678**	0.015	0.463
64	35	Deutz AG	−2.136**	0.046	0.340	−2.283**	0.023	0.417	−0.014	0.859	0.003
65	35	Durkopp Adler AG	−0.717***	0.000	0.857	0.146	0.376	0.079	0.867***	0.002	0.645
66	35	Durr AG	−2.550***	0.002	0.639	−2.528***	0.002	0.648	0.028	0.359	0.084
67	35	GEA Group AG	−0.236	0.118	0.226	−0.128	0.226	0.143	0.114	0.159	0.188
68	35	Gildemeister AG	−0.920	0.139	0.205	−1.966**	0.037	0.367	−1.023***	0.008	0.521
69	35	Jagenberg AG	−0.697***	0.000	0.742	−0.525***	0.002	0.646	0.177**	0.031	0.387
70	35	Junghenrich AG	0.044	0.412	0.068	−0.271***	0.000	0.889	−0.302***	0.001	0.658
71	35	Kloeckner-Werke AG	0.504*	0.053	0.326	0.875**	0.042	0.353	0.414**	0.039	0.360
72	35	Koenig and Bauer AG	−0.368	0.256	0.127	−0.815**	0.021	0.428	−0.429**	0.014	0.469
73	35	Krones AG	−0.211***	0.000	0.721	−0.192***	0.001	0.652	0.023	0.704	0.015
74	35	KSB AG	−0.619***	0.000	0.892	−0.470***	0.000	0.887	0.166**	0.041	0.356
75	35	KUKA AG	−0.934***	0.006	0.548	−0.977***	0.008	0.520	−0.047	0.239	0.135
76	35	Rheinmetall AG	−1.034***	0.000	0.895	−0.891***	0.000	0.835	0.139	0.133	0.211
77	35	Sartorius AG	−0.283***	0.000	0.871	0.247**	0.047	0.339	0.523***	0.000	0.743
78	35	Triumph Adler AG	−0.068	0.773	0.009	−1.227***	0.000	0.804	−1.098***	0.000	0.750
79	35	Vossloh AG	0.252	0.393	0.074	1.231***	0.005	0.564	0.990***	0.000	0.795

Table 5 continued

Nr.	SIC	Firm	WP vs. RM			WP vs. FG			RM vs. FG		
			β	P value	R^2	β	P value	R^2	β	P value	R^2
80	36	Brilliant AG	0.439	0.172	0.178	−0.828**	0.026	0.404	−1.242*	0.054	0.322
81	36	Ceag AG	−0.449***	0.001	0.656	−0.757**	0.028	0.398	−0.359	0.107	0.239
82	36	Leifheit AG	0.118	0.159	0.188	−0.633***	0.004	0.586	−0.687***	0.000	0.725
83	36	M.tech AG	−0.317	0.454	0.057	−0.512	0.244	0.133	−0.203***	0.005	0.563
84	36	Schweizer Electronic AG	−0.053	0.394	0.073	−0.181	0.152	0.194	−0.122	0.420	0.066
85	36	Sedlbauer AG	0.064	0.723	0.013	0.074	0.232	0.139	0.012	0.960	0.000
86	36	Vogt Electronic AG	−0.399**	0.026	0.405	0.089	0.625	0.025	0.446*	0.073	0.286
87	37	Audi AG	−0.093***	0.000	0.922	−0.261**	0.020	0.431	−0.178*	0.084	0.269
88	37	BBS Fahrzeugtechnik AG	0.077	0.630	0.024	0.459***	0.003	0.600	0.366	0.143	0.202
89	37	BMW AG	0.034	0.302	0.106	−0.135	0.219	0.147	−0.173	0.201	0.158
90	37	Hymer AG	−0.128	0.434	0.062	0.251*	0.088	0.263	0.370***	0.001	0.686
91	37	MAN AG	−0.678***	0.009	0.511	−1.679**	0.010	0.497	−1.101**	0.030	0.389
92	37	Porsche AG	0.053	0.796	0.007	−0.260	0.144	0.201	−0.318	0.105	0.241
93	37	Progress-Werke Oberkirch AG	0.580***	0.003	0.607	0.320*	0.075	0.283	−0.263***	0.009	0.506
94	37	Schaltbau Holding AG	−0.286	0.399	0.072	−0.086	0.856	0.003	0.181	0.221	0.146
95	37	Veritas AG	−0.372***	0.000	0.757	−0.184	0.102	0.245	0.206***	0.005	0.558
96	37	Volkswagen AG	−0.048	0.155	0.191	−0.101	0.608	0.027	−0.052	0.794	0.007
97	37	Wanderer-Werke AG	0.115	0.224	0.144	−0.154	0.659	0.020	−0.229	0.523	0.042
98	38	Draegerwerk AG	−0.372*	0.083	0.271	−0.049	0.771	0.009	0.315**	0.010	0.497
99	38	Siemens AG	0.699***	0.002	0.642	0.878***	0.002	0.651	0.191***	0.000	0.728
100	39	Johann F. Behrens AG	−0.669***	0.001	0.696	−0.232	0.143	0.202	0.411	0.149	0.197

t statistic (*$P < 0.1$, **$P < 0.05$, ***$P < 0.01$)

inventory ratios. A better (worse) performance of WP inventory ratios is found in two (two) industries [Hypothesis 4 (b)] when compared to FGs inventory ratios. Finally, RMs inventory ratios show a higher (lower) decreasing or lower (higher) increasing trend in one (three) sector class(es) [Hypothesis 4 (c)] when compared to FGs inventory ratios.

5 Discussion of results

Regarding our results on an aggregated level, we find significantly decreasing total inventory to sales ratios in the textile and wearing apparel, chemical, machinery, and stones, clay, and glass industry. The food industry shows significantly increasing total inventory to sales ratios, which is mainly due to increasing FGs and WP inventory to sales ratios. RM inventories remained nearly stable, and therefore performing relatively "better" when compared to the other inventory stages. The inventory performance in the textile industry can be traced back to the fact of significantly decreasing RMs and WP inventories, whereas RMs performed relatively better than WP inventories. The chemical industry owes its inventory reduction mainly to decreased FGs. Stones, clay, and glass show contrary developments in RMs and FGs inventories: the former are increasing, the latter decreasing, whereas the machinery industry shows a peculiar reduction in WP inventory to sales ratios. Somewhat surprisingly, the transportation equipment industry stands out due to no significant change in total inventory to sales ratios, showing only significantly decreasing WP inventories. But an in-depth analysis of FGs inventories reveals an increase in the second half of our time frame investigated which results in a similar pattern in total inventories, explaining their non-significant regression results.

Observing our results on firm level, a somewhat mixed picture emerges, contrasting the common belief about broad efforts on inventory reduction during the 1990s until present in German corporations. This is even more surprising when we take into account the emerging interest on JIT techniques during the time frame investigated (see Fig. 1).[5]

[5] Therefore, we conducted an exhaustive search using "WISO", the largest German language database for business and economics research articles, and LexisNexis for finding German press articles (newspapers, periodicals, and trade publications). We constrained our search to "JIT". The first German article on JIT accounted for in the WISO database was published in 1982. A first peak in the distribution can be seen around 1989 with a significant decline until 2007. In contrast, the distribution of press articles according to the LexisNexis database starts with the early 1990s and reached a local maximum in 1999. After a short decline, the number of press articles on JIT took off again until reaching their all time high in 2006.

Table 6 Difference in regression coefficients 1993–2005 between inventory stages for SIC classes

SIC	WP vs. RM			WP vs. FG			RM vs. FG		
	β	P value	R^2	β	P value	R^2	β	P value	R^2
20	0.256***	0.003	0.612	0.031	0.574	0.033	−0.214***	0.010	0.506
22/23	0.137***	0.000	0.796	0.100	0.590	0.030	−0.032	0.858	0.003
28	−0.044**	0.024	0.412	0.195***	0.002	0.624	0.243***	0.000	0.829
32	−0.122**	0.012	0.488	0.121***	0.000	0.819	0.245***	0.000	0.785
35	−0.415**	0.011	0.489	−0.343***	0.010	0.504	0.102***	0.003	0.613
37	−0.149***	0.001	0.689	−0.334**	0.013	0.473	−0.178	0.121	0.223

t statistic (*$P < 0.1$, **$P < 0.05$, ***$P < 0.01$)

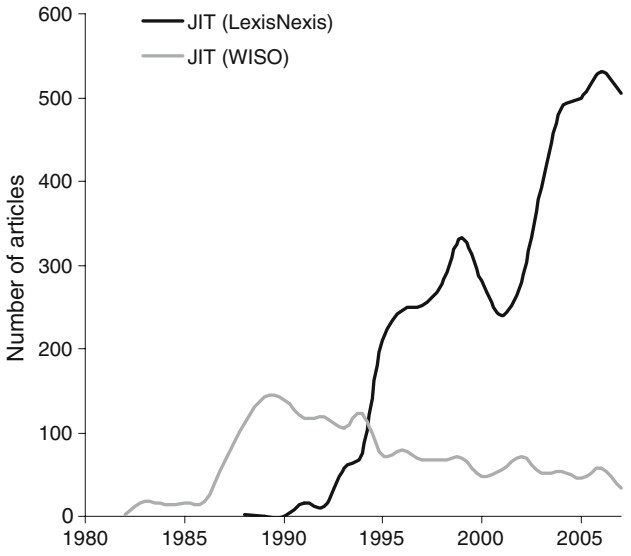

Fig. 1 Distribution of JIT articles 1980–2007 (source: LexisNexis and WISO database)

Nevertheless, half of the firms significantly decreasing total inventories are covered by SIC codes 34–39 (metal fabrication, machinery, electrical equipment, and transportation equipment), thus belonging to industries that are notorious for their use of JIT techniques [27].

It has to be noted that within the time frame analyzed, several firms changed from national (according to German Commercial Code, HGB) to International Financial Reporting Standards (IFRS). We scrutinized for possible conversion effects, resulting in structural interruptions in the data. As a cause, in the majority of cases we identified the accounting of long-term construction contracts, which are no longer reported under inventories but under accounts receivable. Accordingly, we found evidence for such conversion effects mainly in decreasing WP inventories in the machinery industry.[6]

[6] Most likely affected were firms such as Dürr, Koenig and Bauer, KUKA, Linde MAN, Siemens, and Triumph Adler. Therefore, their WP inventory to sales performance should be interpreted carefully.

Table 7 Sensitivity analysis for SIC classes

SIC	ROI (Mean) (%)			ROI (Median) (%)		
	Reduction of TI			Reduction of TI		
	0%	−10%	−50%	0%	−10%	−50%
20	6.62	6.78	7.55	4.70	4.78	5.01
22/23	12.56	12.97	14.93	4.83	4.97	5.66
28	9.58	9.73	10.40	10.05	10.16	10.61
32	6.99	7.07	7.41	7.51	7.63	8.16
35	3.67	3.76	4.13	4.46	4.57	5.06
37	5.43	5.50	5.83	7.95	8.14	8.96
∅	7.48	7.64	8.38	6.17	6.30	6.91

In the literature reviewed, we find ongoing efforts identifying a relationship between inventory and financial performance. This is due to the "critical argument on behalf of inventory reduction… that it will improve the financial position of firms" [7, p. 1025]. Following this paradigm, inventories are not seen as residua of production and operations activities, but as important contributors to a firm's overall success. Nevertheless, executing several regression analyses considering return-on-investment (ROI) or operating margin, we found no evidence for such a relationship.[7] Correspondingly, Cannon [6] recently finds no link between inventory improvements and firm performance. To grasp some helpful insights about the relationship between inventory reduction and financial performance, we performed a sensitivity analysis. We tested on an aggregated and disaggregated level to what extent the ROI could be improved by lowering total inventories ceteris paribus by 10% (50%). Using the mean to determine the ROI for the time frame investigated on an aggregate level, the highest enhancement for a 10% (50%) total inventory reduction can be reached in the textile industry with an ROI increase of 0.41 (2.37) percent points. In the transportation industry and

[7] Furthermore, we found no significant link between the size of a firm (e.g., measured in sales) and its inventory performance.

Table 8 Sensitivity analysis for firms with the best inventory performance

No.	SIC	Firm	β	ROI (Mean) (%)			ROI (Median) (%)		
				Reduction of TI			Reduction of TI		
				0%	−10%	−50%	0%	−10%	−50%
1	20	Sektkellerei Schloss Wachenheim AG	−3.583	7.24	7.30	7.24	6.58	6.77	7.63
2	35	Deutz AG	−3.061	1.70	1.75	2.00	2.35	2.45	2.91
3	35	Dürr AG	−2.430	3.58	3.67	4.12	4.58	4.68	5.13
4	35	Gildemeister AG	−1.777	3.85	3.98	4.61	6.09	6.28	7.19
5	22	Bremer Woll-Kämmerei AG	−1.515	−1.58	−1.58	−1.53	−1.45	−1.50	−1.75
6	28	Linde AG	−1.304	6.43	6.54	6.99	6.38	6.47	6.83
7	35	Koenig and Bauer AG	−1.273	3.82	3.95	4.59	4.73	4.88	5.60
8	35	KUKA AG	−1.174	5.00	5.18	6.08	4.85	5.02	5.83
9	35	Jagenberg AG	−0.986	−0.66	−0.68	−0.80	−2.05	−2.09	−2.29
10	38	Draegerwerk AG	−0.936	5.20	5.34	5.99	5.46	5.61	6.32
∅				3.46	3.55	3.93	4.79	4.95	5.71

Table 9 Sensitivity analysis for firms with the worst inventory performance

No.	SIC	Firm	β	ROI (Mean) (%)			ROI (Median) (%)		
				Reduction of TI			Reduction of TI		
				0%	−10%	−50%	0%	−10%	−50%
1	28	Biotest AG	1.600	5.57	5.77	6.72	5.72	5.94	7.08
2	35	Kloeckner-Werke AG	1.193	5.54	5.67	6.24	4.76	4.86	5.31
3	23	Etienne Aigner AG	0.886	9.64	9.73	10.10	6.17	6.30	6.87
4	32	Erlus AG	0.886	8.68	8.77	9.20	8.82	8.94	9.45
5	22	Textilgruppe Hof AG	0.715	3.56	3.65	4.09	4.37	4.47	4.94
6	32	Rosenthal AG	0.690	−1.08	−1.13	−1.41	2.41	2.49	2.90
7	23	Escada AG	0.629	4.26	4.39	4.98	7.17	7.40	8.48
8	35	Krones AG	0.542	9.26	9.43	10.16	9.28	9.43	10.09
9	22	Vereinigte Filzfabriken AG	0.528	17.22	17.82	20.71	15.56	16.16	19.14
10	23	Hugo Boss AG	0.497	24.03	24.82	28.58	25.09	25.93	29.89
∅				8.67	8.89	9.94	6.67	6.85	7.78

the stone, clay, and glass industry, this effect is with a gain of 0.08 (0.41) percent points negligibly small. Using the median for calculating the aggregated ROI over time, one gets a completely different result concerning the best performing industry, but the improvement effects are even smaller (see also Table 7).

On a disaggregate level, we performed a sensitivity analysis for the ten firms with the highest and lowest significant inventory reduction over the time frame observed (see Tables 8, 9). Comparing the current state of the top ten firms with the bottom ten firms regarding the financial performance, a completely different picture emerges. While the top ten firms have a mean (median) ROI of 3.46% (4.79%), the bottom ten firms stand out with a considerably higher ROI of 8.67% (6.67%). As a first result, it can be stated that the sample firms with a better inventory performance do not excel in terms of the financial performance. The sensitivity analysis underlines this observation. The impact on the mean (median) ROI by a 10% total inventory reduction leads to a 0.09% (0.13) points improvement for the top ten firms in contrast to 0.22% (0.14) points for the bottom ten firms. This effect even becomes stronger for a 50% total inventory reduction resulting in an ROI improvement of 0.47% (0.71) points for the top ten firms, in comparison to 1.27% (0.75) points for the bottom ten firms.

Conducting a sensitivity analysis, it has to be kept in mind that for years with a negative ROI the reduction of total inventories leads to an even smaller ROI. Because the mean (median) ROI is used for the time frame investigated,

potential improvement effects might be canceled out by extraordinary results in one specific year.[8]

In general, we see that the potential contributions of inventory improvements to the financial performance of firms have only been small. These findings might give a direction for further research, seeing inventory not so much as a predictor for financial performance but as what it mainly is: a "buffer" which allows firms to smooth production levels, to shift production to periods with production costs expected to be relatively low, or as precaution for stock-outs. This insight can also be fruitful for managers, as inventory improvements are not necessarily a reliable indicator for a firm's overall performance.

6 Conclusion

Having analyzed inventory performance of 100 German corporations between 1993 and 2005, our findings indicate that the total inventory to sales ratio decreased in a statistically significant extent in four out of six industry sectors during the time frame investigated. On a firm level, we find that half of the firms with a significant decrease in total inventories are based on industry sectors that are especially known for their use of JIT techniques. Further, we pointed out that potential contributions of inventory reductions to the financial performance of firms are only of a small degree.

There are several limitations regarding the empirical findings presented above and the conclusions derived from them. Some of these limitations raise further research opportunities. As discussed above, the cause and effect relationship between inventory holdings and financial performance (et vice versa) is still nebulous. While it is clear that, ceteris paribus, lower inventories cause higher return on assets, this relationship does not necessarily hold in the real world which does not offer a ceteris paribus opportunity in most cases. As mentioned before, a good inventory policy necessarily deals with trade-off decisions. Inventory holding costs money but is not always bad. Accordingly, it would be interesting to investigate the links, e.g., between higher customer service levels or better quality control and inventory levels or the impact of postponement strategies on different inventory stages; or the effects of global sourcing strategies, outsourcing or off-shoring production activities on inventory holding. Increasing and more variable lead times due to longer transportation would result in higher stocks. Furthermore, the analysis of changes in factor prices as well as concentration tendencies in several industries on inventory performance could be helpful to explain industry-specific developments. From a financial accounting perspective, further research is needed to better understand degree and direction of possible conversion effects on inventory holdings reported under local versus international accounting standards. Finally, to better understand the different causes for the inventory development analyzed, our research could be pursued using case study research design. Generating extensive examinations of each case could explore similar patterns of firms with high or low inventory performance or within different industries, for example. We did not offer this research, but paved the way.

[8] To demonstrate the potential extent of this cannibalization effect, we take a closer look at the ROI from 1994 of Sektkellerei Schloss Wachenheim AG: in this particular year, the firm has an ROI of −90.77%. Because the total inventories represent 62.89% of the total capital employed the results of the sensitivity analysis have such a deep impact that all positive effects of the remaining 12 years are eaten up. As a result, there is no recognizable increase in the mean ROI even if total inventory would be reduced by 50%. If we would exclude this specific year, a mean ROI of 15.40% could be achieved and the sensitivity analysis in the case of 50% reduction of total inventories would lift the mean ROI up to 18.87%. In this specific case, the effect can reduced to a minimum using the median.

References

1. Bairam EI (1996) Disaggregate inventory-sales ratios over time: the case of US companies and corporations, 1976–92. Appl Econ Lett 3:167–169
2. Balakrishnan R, Linsmeier TJ, Venkatachalam M (1996) Financial benefits from JIT adoption: effects of customer concentration and cost structure. Account Rev 71:183–205
3. Biggart TB, Gargeya VB (2002) Impact of JIT on inventory to sales ratios. Ind Manag Data Syst 102:197–202
4. Blinder AS, Maccini LJ (1991) Taking stock: a critical assessment of recent research on inventories. J Econ Perspect 5:73–96
5. Canjels E, Watson MW (1997) Estimating deterministic trends in the presence of serially correlated errors. Rev Econ Stat 79:184–200
6. Cannon AR (2008) Inventory improvement and financial performance. Int J Prod Econ 115:581–593
7. Chen H, Frank MZ, Wu OQ (2005) What actually happened to the Inventories of American Companies Between 1981 and 2000. Manag Sci 51:1015–1031
8. De Haan J, Yamamoto M (1999) Zero inventory management: facts or fiction? Lessons from Japan. Int J Prod Econ 59:65–75
9. Durbin J, Watson GS (1950) Testing for serial correlation in least squares regression. I. Biometrika 37:409–428
10. Durbin J, Watson GS (1951) Testing for serial correlation in least squares regression. II. Biometrika 38:159–178
11. Greene WH (2008) Econometric analysis, 6th edn
12. Hayes RH (1981a) Why Japanese factories work. Harvard Bus Rev 59:56–66
13. Hirsch AA (1996) Has inventory management in the US become more efficient and flexible? A macroeconomic perspective. Int J Prod Econ 45:37–46
14. Huson M, Nanda D (1995) The impact of just-in-time manufacturing on firm performance in the US. J Operat Manag 12:297–310
15. Kobayashi M (1985) Comparison of efficiencies of several estimators for linear regressions with autocorrelated errors. J Am Stat Assoc 80:951–953

16. Lieberman MB, Demeester L (1999) Inventory reduction and productivity growth: linkages in the Japanese automotive industry. Manag Sci 45:466–485
17. Little JD (1961) A proof of the Queuing formula: $L = \lambda W$. Operat Res 9:383–387
18. Monden Y (1981a) What makes the Toyota production system really tick? Ind Eng 13:36–46
19. Monden Y (1981b) Adaptable Kanban system helps Toyota maintain just-in-time production. Ind Eng 13:29–46
20. Nahmias S (2009) Production and operations analysis, 6th edn
21. Nakane J, Hall RW (1983) Management specs for stockless production. Harvard Bus Rev 61:84–91
22. Park RB, Mitchell BM (1980) Estimating the autocorrelated error model with trended data. J Econ 13:185–201
23. Prais SJ, Winsten CB (1954) Trend estimation and serial correlation, Cowles Commission Discussion Paper Statistics, no. 383
24. Savin NE, White KJ (1977) The Durbin–Watson test for serial correlation with extreme sample sizes or many regressors. Econometrica 45:1989–1996
25. Schonberger RJ (1982) Japanese manufacturing techniques
26. Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling, 3rd edn
27. Swamidass PM (2007) The effect of TPS on US manufacturing during 1981–1998: inventory increased or decreased as a function of plant performance. Int J Prod Res 45:3763–3778
28. Tribó JA (2009) Firms' stock market flotation: effects on inventory policy. Int J Prod Econ 118:10–18
29. Vollmann TE, Berry WL, Whybark DC, Jacobs FR (2005) Manufacturing planning and control for supply chain management, 5th edn
30. Wooldridge JM (2006) Introductory econometrics: a modern approach, 3rd edn