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Variable versus fixed weighted aggregate inventory to sales ratios: the effect on long-term trends for Germany

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Abstract This study is aimed at analyzing the difference of using fixed weight aggregate inventory to sales ratios rather than "traditional", that is, variable weighted, aggregated inventory to sales ratios. It shows that interpretations of these ratios may be problematic because different aggregation methods are signaling different time trends under certain circumstances. Analyzing the inventory performance of German corporations between 1993 and 2005, we find that the total inventory to sales ratio decreased in a statistically significant extent in the majority of industry sectors during the period investigated. Considering the effects of using fixed aggregation weights on our results, some changes concerning significance of results occur. The additional use of fixed aggregation weights is helpful because it isolates any trends observed in the aggregated inventory to sales ratio series to fluctuations in the underlying (sub) sectors' inventory to sales ratio, not shifts in the composition of the aggregate.

Keywords Inventory · Inventory to sales ratios · Measurement · Trends · Time series analysis

1 Empirical inventory research and data aggregation problems

Inventory reduction is a prevalent topic in business research and practice. Many articles and case studies have been written about firms' needs and efforts to reduce inventories. Many of them refer to concepts such as "just-in-time" (JIT) or "zero inventory" arguing that inventory reflects waste and should be eliminated causing productivity to rise [6, 11, 15]. From the managerial viewpoint, it is therefore necessary to measure and control inventory holdings both at the level of specific processes and on firm level. From the viewpoint of empirical research, inventory performance over time could be studied either on firm or on industry level. In the majority of cases, firm-level data are publicly available for stock-listed corporations, which could be aggregated to industry level. Aggregated industry level data are also available from several official institutions conducting their own firm-level databases aggregating them on industry level.

There are only few empirical studies analyzing inventory performance over time. With respect to national economies, there is only one country in which inventories are sufficiently studied: the United States (US). Blinder and Maccini [2] 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 since computerization should have reduced the need for inventories as buffers" [[2], p. 79]). The result of Blinder and Maccini [2], based on aggregate data, served as point of departure for a series of other studies mainly concerned with inventory levels, mainly in the US. Loar [14], for example, studied a sample of 72 firms between 1970 and 1987 aggregating them into four manufacturing sectors (chemical, food, electronics, and pharmaceutical), where he finds significant reductions in the levels of inventory to sales ratios. Rajagopalan and Malhotra [18], using aggregate industry data published by the US Department of Commerce Bureau of Economic Analysis, observe in a majority of the 20 manufacturing sectors analyzed decreasing raw material and work-in-process inventories during the period

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between 1961 and 1994. Irvine [12], also analyzing aggregate inventory to sales ratios, published by the US Department of Commerce Bureau of Economic Analysis, finds sharp downtrends in US manufacturing inventory to sales ratios since the early 1980s, which have occurred mainly in manufacturing sectors carrying durable goods on all three inventory stages (raw materials, work-in-process, and finished goods), while nondurable goods manufacturers remained at nearly the same inventory level on average. Since the mid-1980s merchant wholesalers and since 1990 retailers carrying durable goods have significantly reduced their inventory to sales ratios. Nondurable goods manufacturers, wholesalers, and retailers show upward inventory trends. After investigating the inventories of 7.433 US manufacturing firms, Chen et al. [3] report that while "the medians of raw materials, finished goods, and total inventory days drop, the means actually rise between 1981 and 2000" (p. 1021). Focusing on medians as means may be influenced by outliers they find a significantly decreasing time trend for total inventories, raw materials, and work-in-process. While work-in-process inventories declined most significantly, finished goods inventories show nearly no trend. Chen et al. [4] continued their study design for 1662 US wholesale and retails firms between 1981 and 2004. While wholesalers increased their inventory turnover by about 3% per year over the period, retailers kept their inventory turns fairly constant until 1995. After 1995, retail firms also started to improve the inventory turnover. Analyzing panel data from quarterly financial reports of 311 US retailers, Gaur et al. [9] find downward sloping inventory turnover ratios during 1987–2000. This result is surprising in so far as capital intensity has increased as well and is positively correlated with inventory turnover. Based on aggregate US industry level data, Shah and Shin [19] find that inventory levels trended downwards in the manufacturing sector, which occurred rapidly during the 1990s. However, their analysis indicates that the average inventory levels have trended upwards for both the retail and wholesale sectors. Outside the US empirical inventory research is largely unexplored [5]. This is the more surprising as there is much capital tied up in inventories, costing firms (not only in recession times) a lot of money. For example, at the end of 2005, German businesses held more than 400 billion EUR worth of inventory. Obermaier and Donhauser [16] analyze inventory performance of 100 German stock-listed corporations. On firm level, they find that half of the firms with a significant decrease in total inventories are based in industry sectors that are especially known for their use of JIT techniques. Aggregating these firm-level data, their 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.

On the one hand, this study is interested on how inventory data could be aggregated from firm to industry level. This study is analyzing the difference in using fixed weight aggregate inventory to sales ratios rather than "traditional", that is, variable weighted, aggregated inventory to sales ratios. Difficulties arise because different aggregation methods are signaling different time trends under certain circumstances. Hence our main research question is "Which problems arise in analyzing time trends of inventory to sales ratios when data are aggregated using 'traditional', that is, variable weighted, aggregated inventory to sales ratios compared to the use fixed weight aggregate inventory to sales ratios?" We will discuss the implications of these methods and illustrate them not only by artificial examples but also by applying them on real-life data of inventory to sales ratios of German firms. Among total inventories, inventories are analyzed on each stage of the production process individually, that is, raw materials, work-in-process, and finished goods.

The article is organized as follows: In the following section, we will present alternative methods of aggregating inventory ratios, for example, from firm to industry level, and illustrate them by example. In the subsequent section, we apply these methods on actual inventory data of a sample of German stock-listed companies and discuss their implications in the analysis of time trends. We conclude with recommendations, limitations, and further research opportunities.

2 Different aggregation methods and problem illustration

Studying inventory performance on firm level, a widely used ratio is inventory to sales (IS). 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:

$$IS_{it} = \frac{I_{it}}{S_{it}}. \tag{1}$$

Studying inventory performance on industry level, firm-level data have to be aggregated. The "traditional" approach is to simply divide the sum of inventories across firms by the sum of sales across firms. We apostrophize this approach as "traditional" as it is the common approach in inventory research using aggregate data.

In order to calculate such "traditional" aggregate, IS 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:

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

This can be reformulated as:

$$IS_{jt}^{\text{vaw}} = \frac{S_{1t}}{\sum_{i=1}^{n} S_{it}} \frac{I_{1t}}{S_{1t}} + \frac{S_{2t}}{\sum_{i=1}^{n} S_{it}} \frac{I_{2t}}{S_{2t}} + \cdots + \frac{S_{nt}}{\sum_{i=1}^{n} S_{it}} \frac{I_{nt}}{S_{nt}}. \quad (3)$$

By Eq. 3, it is obvious that the aggregation weight $S_{it}/\sum_{i=1}^{n} S_{it}$ of a particular firm's IS ratio is its proportion of aggregate sales in this industry. Fluctuations in these time-variable aggregation weights may cause shifts in the aggregate IS ratio that are unrelated to shifts in the underlying IS ratios from year to year, which can be misleading in the case when changes in the variable aggregation weights dominate the shifts in the individual IS ratios, which are similar to a current weighted Paasche index.[1] Although Paasche index numbers have the advantage of reflecting the actual and current situation in a certain period of time, there are serious difficulties in interpreting runs of Paasche index numbers because of these varying weights over time (e.g. [1]).

These interpretation problems can be resolved using a Laspeyres index with fixed aggregation weights (*faw*) $S_{i\tau}/\sum_{i=1}^{n} S_{i\tau}$ with respect to a certain base year τ instead of variable weights in Eq. 3. This aggregation calculus also holds for aggregating from sectors instead of firms. Hence, we obtain:

$$IS_{jt}^{\text{faw}(\tau)} = \frac{S_{1\tau}}{\sum_{i=1}^{n} S_{i\tau}} \frac{I_{1t}}{S_{1t}} + \frac{S_{2\tau}}{\sum_{i=1}^{n} S_{i\tau}} \frac{I_{2t}}{S_{2t}} + \cdots + \frac{S_{n\tau}}{\sum_{i=1}^{n} S_{i\tau}} \frac{I_{nt}}{S_{nt}}. \quad (4)$$

Generally speaking, using fixed aggregation weights assures that any trend observed in the time series of the aggregated IS ratios is caused by variations in the underlying firms' IS ratios. Hence, it is argued that runs of Laspeyres index numbers can be better compared and interpreted. Nevertheless, the disadvantage of this index number is that the actual and current situation is only represented for the base year period. Furthermore, the researcher has to choose which base year τ to use. Three alternative years are regularly used in ex-post analyses: the first, the middle (if the length of the period is odd-numbered), and the last (e.g. current) year of the time frame investigated. While a time series of aggregated IS ratios using the last (first) year as base year measures up to the variable aggregated time series exactly in the last (first) year, using the mid-year has an analogous effect and may be reasonable when studying a particular historical period.

In order to better understand the use and interpretation of these different aggregation methods, we will illustrate them via a numerical example (Table 1) that extends a problem description proposed by Irvine [13].

We observe four firms over four periods in our hypothetical sample. In period 1, they all achieve 100 EUR sales but differ in inventories ranging from 500 to 100 EUR, which implies IS ratios ranging from 5 to 1. The "traditional" aggregate IS ratio using variable aggregation weights (*vaw*) can be calculated by dividing the sum of inventories by the sum of sales; hence, the aggregated IS ratio is 3. In period 2, we observe firm 1 doubling sales and inventory. Hence, its IS ratio remains stable at 5. But the aggregated IS ratio increases to 3.4. In period 3, we find firm 4 doubling sales and inventories, while firm 1 falls back to its original values. Again, the individual IS ratios do not change compared to period 1. But the aggregated IS ratio now decreases to 2.6. Although we detect no change in the underlying IS ratios on firm level in periods 2 and 3, the aggregated IS ratio may fluctuate in two different directions. In period 4, finally, we can see an actual increasing IS ratio of firm 4. But while the other firm's IS ratios remain constant; we would expect an aggregated IS

Table 1 Numerical example

Firm	Inventory	Sales	IS ratio		
			vaw	*faw* (period 1)	*faw* (period 4)
Period 1					
1	500 €	100 €	5	5	5
2	400 €	100 €	4	4	4
3	200 €	100 €	2	2	2
4	100 €	100 €	1	1	1
Total	1.200 €	400 €	3	3	2.6
Period 2					
1	1.000 €	200 €	5	5	5
2	400 €	100 €	4	4	4
3	200 €	100 €	2	2	2
4	100 €	100 €	1	1	1
Total	1.700 €	500 €	3.4	3	2.6
Period 3					
1	500 €	100 €	5	5	5
2	400 €	100 €	4	4	4
3	200 €	100 €	2	2	2
4	200 €	200 €	1	1	1
Total	1.300 €	500 €	2.6	3	2.6
Period 4					
1	500 €	100 €	5	5	5
2	400 €	100 €	4	4	4
3	200 €	100 €	2	2	2
4	300 €	200 €	1.5	1.5	1.5
Total	1.400 €	500 €	2.8	3.125	2.8

[1] Hence we add the superscript for variable aggregation weights (*vaw*) to the IS ratio symbol in Eqs. 2 and 3.

ratio being higher compared to period 1. Nevertheless, we find it decreasing to 2.8.

Obviously, our example clearly illustrates that shifting IS ratios on firm level do not necessarily lead to according shifts on an aggregate level. This would only be true if the mixture of sales remained stable over time. Irvine [13] concludes: "Hence with the composition of sales remaining the same, movements in the aggregate IS ratio accurately reflect changes in the underlying […] IS ratios. This, however, is not the case when the composition of sales shifts […]." Instead, the example given illustrates that shifts in sales mixture may actually countervail shifts in IS ratios on firm level leading to shifts in aggregate IS ratios in the contrarian direction.

Referring to Eq. 3, we can see that a firm's aggregation weight $S_{it} / \sum_{i=1}^{n} S_{it}$ increases if its sales grow at a higher rate compared to total sales. But the effect this has on the aggregate IS ratio depends further on the level of a single firm's IS ratio: is it higher (lower) than average than an increasing aggregation weight will lead an increasing (decreasing) aggregate IS ratio. This is the case in our example comparing period 1 with period 2 and period 3, respectively. In period 4, we see increasing aggregation weights and IS ratios as well for firm 4. But as the IS ratio of firm 4 remains below average, the effect is more than absorbed. Hence, the aggregated IS ratio decreases to 2.8.

Using fixed aggregation weights $S_{i\tau} / \sum_{i=1}^{n} S_{i\tau}$ with respect to a certain base τ year instead of these traditional variable weights can assure that any trend observed in the time series of the aggregated IS ratios is caused by shifts in the underlying firms' IS ratios but not by shifts in aggregation weights. Referring back to our example, we will consider two cases: the first with period 1 as base year and the second with period 4 as base year. Hence, the fixed aggregation weights are equally a quarter for each firm in the first case. Accordingly, we find constant aggregated IS ratios for the first three periods because the individual IS ratios are also constant. Only in period 4, where the IS ratio of firm increases, this shift upwards is correctly reflected using fixed aggregation weights. These observations also hold for the second case with period 4 as base year.

3 Discussion of the problem using German aggregate inventory to sales ratios

After illustrating the problems that might occur when interpreting time series of aggregate IS ratios based on variable aggregation weights, we go further by applying the different aggregation methods on data of IS ratios of German firms in order to analyze their implications in inventory performance over time. The study is based on disaggregated data on firm level using the sample of Obermaier and Donhauser [16]. With respect to the research question stated above, this study is aimed at analyzing the difference of using fixed weight aggregate IS ratios rather than "traditional", that is, variable weighted, aggregated IS ratios that are commonly used. Among total inventories, inventories are analyzed on each stage of the production process individually, that is, raw materials, work-in-process, and finished goods.

The sample chosen spans the time frame from 1993 to 2005 and covers 100 firms listed at the German stock market.[2] The firms in the sample are assigned to the Standard Industrial Classification (SIC) manufacturing division, which includes firms engaged in the mechanical or chemical transformation of materials or substances into new products. This division is 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 mainly 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. Accordingly, firm-level data were aggregated on industry level according to these SIC codes on a two-digit basis. For the case that some two-digit SIC code sectors in our sample contained a too small number of firms to calculate meaningful aggregate IS ratios, we used the firms secondary industry sector assignments.[3] Thus, we could achieve that all SIC code sectors are comprised of at least ten firms. With only a set of six firms, SIC 30 is the sole exception, because it was impossible, to reassign the companies in a sensible way. We have furthermore merged the SIC codes 22 and 23 due to their similarity. The result of our aggregation spans eight industry sector classes.

In order to better understand the degree of improvement at each of the different inventory stages as well as potential shifts between them, IS ratios can be analyzed separately for total inventories as well as its constituents: raw material (RM), work-in-process (WP), and finished goods (FG). Total inventory is defined as the sum of these three components.

[2] See Appendix. As an indicator for relative size, each firm's proportion of the corresponding SIC industry class sales on average is also reported.

[3] For example: SIC 33: 1 firm, SIC 34: 3 firms, SIC 38: 2 firms, SIC 39: 1 firm. For rearranging the Thomson Financial's Worldscope Global Database offers up to eight different SIC codes per firm, whereas the ranking depends on the extent of a firm's activities.

A linear regression model with time (i.e., year) as independent variable is applied in order to investigate the rate of change in inventory ratios over time. To assess the corresponding overall trend coefficients for our sample over time, a simple linear regression model for total inventory levels as well as for each of the three inventory types is applied:

$$IS_{it} = \alpha_i + \beta_i t + \varepsilon_i, \quad (5)$$

In Eq. 5, t represents the time period (year), α_i the intercept, and β_i the slope, that is, the trend coefficient, of firm i. In order to check for first-order autocorrelation of the residuals ε_i, we are conducting the Durbin-Watson test statistic [7, 8]. Applying the Durbin-Watson test, we found first-order autocorrelation in nearly all of the time series in the sample. As main consequence, OLS test statistics are no longer valid because standard errors are biased and, therefore, causing serious misleading signals [10, 20]. In order to take autocorrelation into account, iterated Prais-Winsten estimation is employed [17].

For a brief overview of the industries analyzed, their SIC classifications, the means, medians, and variation coefficients of the different IS ratios are given in Table 2. The variation coefficients indicate the relative degree of movements inside a sector's inventory ratios.

On an aggregated level (SIC classes), the results of our time series regression analysis are provided in Table 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.

Using variable aggregation weights (*vaw*), total IS ratios decreased (increased) significantly in four (two) sectors. Raw material IS ratios decreased (increased) significantly in two (three) industry sector(s). Work-in-process IS ratios decreased (increased) significantly in five (two) industries. Finished goods IS ratios decreased (increased) significantly in four (one) sector(s).

Using fixed aggregation weights with the first year as base year (*faw*1993), total IS ratios decreased (increased) significantly in three (one) sector(s). Raw material IS ratios decreased (increased) significantly in one (two) industry sector(s). Work-in-process IS ratios decreased (increased) significantly in five (two) industries. Finished goods IS ratios decreased (increased) significantly in three (one) sector(s).

Using fixed aggregation weights with the mid-year as base year (*faw* 1999), total IS ratios decreased (increased) significantly in four (one) sector(s). Raw material IS ratios decreased (increased) significantly in one (one) industry sector. Work-in-process IS ratios decreased (increased) significantly in four (two) industries. Finished goods IS ratios decreased significantly in four sectors. No significant increase was found.

Further, on applying fixed aggregation weights with the final year as base year (*faw* 2005), total IS ratios decreased (increased) significantly in four (one) sector(s). Raw material IS ratios show no significant shift at all. Work-in-process IS ratios decreased (increased) significantly in four (two) industries. Finished goods IS ratios decreased significantly in four sectors. Again no significant increase was found. All these findings are summarized in Table 4.

On a further aggregated level, the regression results for our sample in total are provided in Table 5, whereas aggregation was executed from firms as well as from the SIC code classes (sectors). It is remarkable that no decreasing IS ratios are found (with one exception) on that level of aggregation. These results will be discussed in the following.

Table 2 Descriptive measures 1993–2005 (SIC code classes)

SIC	TI			RM			WP			FG			Proportion of total sales (%)
	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	
20	11.87	7.50	96.83	3.69	2.55	76.47	3.02	0.89	221.42	5.16	2.74	115.56	2.39
22/23	19.11	18.04	34.67	4.25	4.32	64.83	2.72	2.50	98.68	12.15	12.04	47.51	2.35
28	17.93	15.49	50.27	4.51	4.02	59.37	4.13	1.38	170.43	9.29	7.95	37.76	25.62
30	13.58	14.48	33.78	4.72	4.52	26.90	2.74	1.54	101.89	6.12	5.75	73.76	2.52
32	15.51	12.68	50.72	3.83	3.46	62.97	3.03	1.29	135.38	8.65	6.78	64.69	3.01
35	21.60	20.47	45.25	5.19	4.91	53.14	9.79	6.91	91.76	6.61	4.73	81.43	8.47
36	18.22	17.17	28.49	6.02	5.69	43.20	5.65	4.16	78.76	6.55	5.45	70.25	18.20
37	17.62	14.37	51.60	4.25	3.73	66.43	5.64	3.69	97.07	7.73	7.35	57.54	37.43
Total	17.57	16.15	51.72	4.56	4.18	59.80	5.07	2.87	131.46	7.94	6.87	70.16	100.00

Table 3 Overall trend coefficients for SIC classes 1993–2005

SIC	TI			RM			WP			FG		
	β	p-value	R^2	β	p-value	R^2	β	p-value	R^2	β	p-value	R^2
vaw												
20	0.6058***	0.0010	0.6793	0.0441***	0.0063	0.5417	0.3008***	0.0011	0.6705	0.2618***	0.0042	0.5755
22/23	−0.4390***	0.0062	0.5442	−0.1936***	0.0000	0.8852	−0.0671**	0.0108	0.4937	−0.1695	0.3131	0.1014
28	−0.2716***	0.0000	0.9037	0.0246	0.3988	0.0721	−0.0547***	0.0068	0.5354	−0.2532***	0.0000	0.8401
30	−0.5093***	0.0000	0.8391	−0.0228	0.3279	0.0957	−0.0861***	0.0000	0.8356	−0.4004***	0.0000	0.8765
32	−0.0928**	0.0105	0.4966	0.0885**	0.0178	0.4450	−0.0268	0.1062	0.2397	−0.1443***	0.0000	0.8869
35	−0.1862	0.1552	0.1912	0.1108***	0.0051	0.5606	−0.3004**	0.0204	0.4308	0.0084	0.6831	0.0174
36	0.4372**	0.0485	0.3353	−0.0124	0.6280	0.0244	0.6445***	0.0048	0.5648	−0.2012***	0.0000	0.9414
37	−0.0255	0.8150	0.0057	−0.0226*	0.0977	0.2503	−0.1727***	0.0000	0.8491	0.1497	0.2014	0.1575
faw (1993)												
20	0.2792	0.1450	0.1999	0.0433***	0.0016	0.6485	0.1835**	0.0227	0.4199	0.0448	0.6881	0.0168
22/23	−0.1664	0.1291	0.2148	−0.0737***	0.0002	0.7542	−0.0530**	0.0142	0.4673	−0.0459	0.5823	0.0313
28	−0.1898***	0.0000	0.8219	0.0360	0.2493	0.1302	−0.0729***	0.0001	0.8152	−0.1641***	0.0003	0.7475
30	−0.4869***	0.0000	0.8548	0.0090	0.6892	0.0167	−0.0677***	0.0002	0.7634	−0.4281***	0.0000	0.8993
32	−0.0011	0.9778	0.0001	0.0321	0.3961	0.0729	0.0149	0.3505	0.0875	−0.0406	0.1665	0.1821
35	−0.2472**	0.0183	0.4422	0.0837*	0.0908	0.2594	−0.3127***	0.0009	0.6812	−0.0407	0.1787	0.1730
36	0.4394**	0.0499	0.3321	−0.0153	0.5653	0.0342	0.6472***	0.0050	0.5627	−0.1980***	0.0000	0.9424
37	0.1289	0.1410	0.2036	−0.0146	0.2095	0.1524	−0.1352***	0.0032	0.5982	0.2327*	0.0631	0.3040
faw (1999)												
20	0.2839	0.2658	0.1220	0.0258*	0.0759	0.2816	0.1988*	0.0783	0.2778	0.0468	0.7563	0.0101
22/23	−0.4743***	0.0041	0.5778	−0.0266***	0.0099	0.5021	−0.0146	0.3940	0.0735	−0.4346***	0.0058	0.5502
28	−0.2427***	0.0000	0.8975	0.0194	0.4448	0.0595	−0.0872***	0.0000	0.8440	−0.1825***	0.0002	0.7720
30	−0.5357***	0.0000	0.8558	−0.0069	0.7711	0.0089	−0.0656***	0.0000	0.8240	−0.4636***	0.0000	0.9011
32	0.0288	0.2548	0.1274	0.0554	0.1821	0.1706	−0.0006	0.9590	0.0003	−0.0263	0.5583	0.0354
35	−0.4539***	0.0001	0.8058	0.0500	0.1945	0.1621	−0.5063***	0.0000	0.9278	−0.0087	0.7659	0.0093
36	0.4394**	0.0469	0.3393	−0.0145	0.5670	0.0339	0.6504***	0.0045	0.5698	−0.2025***	0.0000	0.9428
37	0.1033	0.2841	0.1136	−0.0128	0.2821	0.1145	−0.1041***	0.0038	0.5844	0.1897	0.1213	0.2228
faw (2005)												
20	0.2727	0.2809	0.1150	0.0243	0.1039	0.2425	0.1963*	0.0880	0.2634	0.0416	0.7812	0.0081
22/23	−0.3925**	0.0155	0.4588	−0.0181	0.1028	0.2438	0.0411	0.2918	0.1102	−0.4294***	0.0056	0.5524
28	−0.2721***	0.0000	0.8880	0.0240	0.3957	0.0730	−0.0983***	0.0000	0.8366	−0.2044***	0.0002	0.7770
30	−0.5464***	0.0000	0.8560	−0.0080	0.7320	0.0123	−0.0665***	0.0001	0.8105	−0.4722***	0.0000	0.8994
32	0.0287	0.2823	0.1144	0.0557	0.2069	0.1541	−0.0104	0.3965	0.0728	−0.0154	0.7216	0.0133
35	−0.4482***	0.0000	0.8833	0.0522	0.1194	0.2248	−0.4812***	0.0000	0.9698	−0.0265	0.1676	0.1813
36	0.4333**	0.0471	0.3387	−0.0140	0.5823	0.0313	0.6456***	0.0044	0.5719	−0.2041***	0.0000	0.9422
37	0.0969	0.3160	0.1002	−0.0119	0.3191	0.0990	−0.0922***	0.0043	0.5738	0.1778	0.1328	0.2112

t-statistic (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Regarding our results on an aggregated level based on variable weights, we find remarkably decreasing total IS ratios in the rubber and plastics, textile and wearing apparel, and chemical industry. A slight but nevertheless significant increase can be found in the stones, clay, and glass industry. The achievements in the rubber industry are due to decreasing finished goods inventories over the whole time frame. The inventory performance in the textile industry can be traced back to the fact of decreasing raw materials and work-in-process inventories over the whole time frame investigated, whereas in the second half we find efforts in reducing finished goods inventories. The chemical industry owes its inventory reduction mainly in decreased finished goods and work-in-process inventories. The food sector shows significantly increasing total IS ratios, which is mainly due to increasing work-in-process

Table 4 Number of significant de-/increasing SIC classes 1993–2005

	vaw		*faw* (1993)		*faw* (1999)		*faw* (2005)	
	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)
TI	4	2	3	1	4	1	4	1
RM	2	3	1	2	1	1	0	0
WP	5	2	5	2	4	2	4	2
FG	4	1	3	1	4	0	4	0

(±) denotes significant de-/increasing SIC classes

Table 5 Overall trend coefficients for total sample 1993–2005

SIC	TI			RM			WP			FG		
	b	*p*-value	R^2	*b*	*p*-value	R^2	*b*	*p*-value	R^2	*b*	*p*-value	R^2
vaw												
Total (firms)	−0.0401	0.5228	0.0420	−0.0082	0.3599	0.0843	−0.0017	0.9524	0.0004	−0.0324	0.3868	0.0757
Total (sectors)	−0.0401	0.5228	0.0420	−0.0082	0.3599	0.0843	−0.0017	0.9524	0.0004	−0.0324	0.3868	0.0757
faw (1993)												
Total (firms)	0.0241	0.6905	0.0165	0.0172	0.1116	0.2335	0.0217	0.4882	0.0492	−0.0143	0.6720	0.0187
Total (sectors)	−0.0213	0.6938	0.0162	0.0129	0.1943	0.1622	0.0160	0.5541	0.0361	−0.0535*	0.0930	0.2564
faw (1999)												
Total (firms)	0.0087	0.8990	0.0017	0.0044	0.5807	0.0316	0.0238	0.4838	0.0502	−0.0233	0.5588	0.0353
Total (sectors)	−0.0136	0.8324	0.0047	0.0042	0.6108	0.0269	0.0210	0.5198	0.0426	−0.0420	0.2525	0.1285
faw (2005)												
Total (firms)	−0.0049	0.9419	0.0006	0.0053	0.5416	0.0384	0.0134	0.6550	0.0208	−0.0308	0.4813	0.0508
Total (sectors)	−0.0290	0.6457	0.0220	0.0022	0.7977	0.0069	0.0030	0.9189	0.0011	−0.0383	0.3342	0.0933

t-statistic (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

IS ratios. The electronics and electrical equipment sector, which is in our sample dominated by the Siemens AG, shows a significant increase in total inventories, which can be explained by strongly increasing work-in-process inventories in the second half of our time frame investigated. Nevertheless, we also find a significant reduction in finished goods inventories in this sector.

Considering the effects of using fixed aggregation weights on our results (with 1993 as base period), some changes concerning significance of results occur, while the results remain stable for rubber and plastics, chemicals, and electronics. The major changes are that the increasing (decreasing) effect in the food (textiles and wearing apparel) industry becomes nonsignificant. Furthermore, the so far nonsignificant decrease in total inventories in the machinery industry becomes significant. These changes also hold for other base periods (1999 and 2005), with the textiles and wearing apparel as an exception remaining significant.

Analyzing the food industry first, we see consistently increasing total IS ratio in the second half of the time frame. In the first half, we find a decrease when using fixed aggregation weights, in contrast to a constant trend using variable weights (see Fig. 1). Obviously, the decrease in IS ratios in the years until 1999 is covered by a shift in sales.

Analyzing the textiles and wearing apparel industry next, we have divergent results only when using 1993-based fixed weights. This has a lot to do with strong efforts in reducing finished goods inventories in the second half of the time frame (see Fig. 2), which is clearly underestimated when using 1993 as base period (see Fig. 3).

The chemical sector (see Fig. 4) as well as rubber and plastics (Fig. 5) shows clear and consistent results independent from which aggregated IS ratios are calculated.

The sector stones, clay, and glass show a slight decreasing trend when using variable weights. This does not hold for any fixed aggregation weight (see Fig. 6). The reason can be found in finished goods inventories showing a decreasing trend when using variable weights,

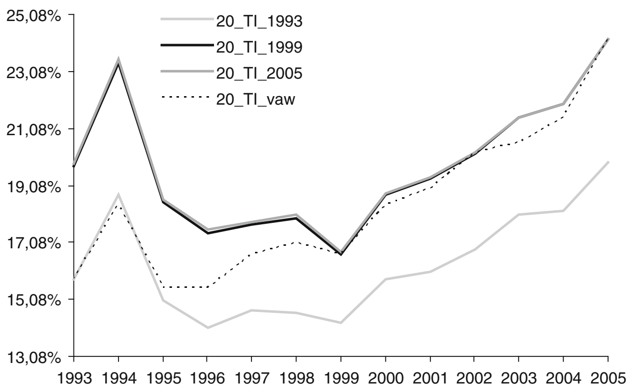

Fig. 1 Food—total inventory to sales ratio 1993–2005

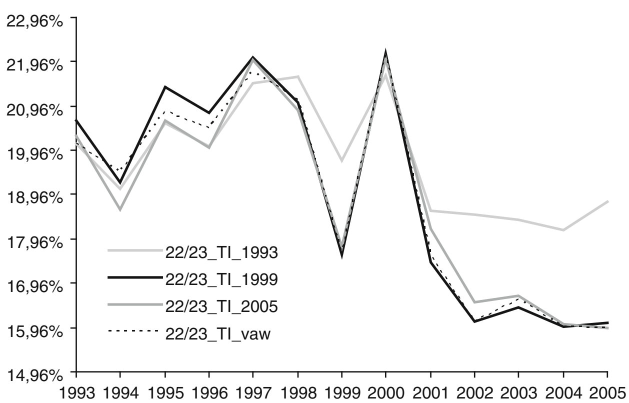

Fig. 2 Textiles and wearing apparel—total inventory to sales ratio 1993–2005

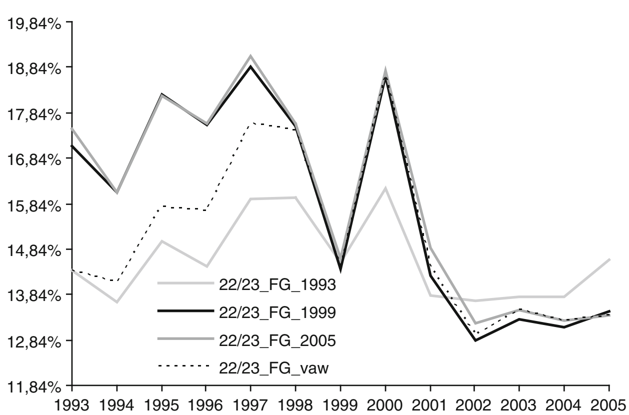

Fig. 3 Textiles and wearing apparel—finished goods inventory to sales ratio 1993–2005

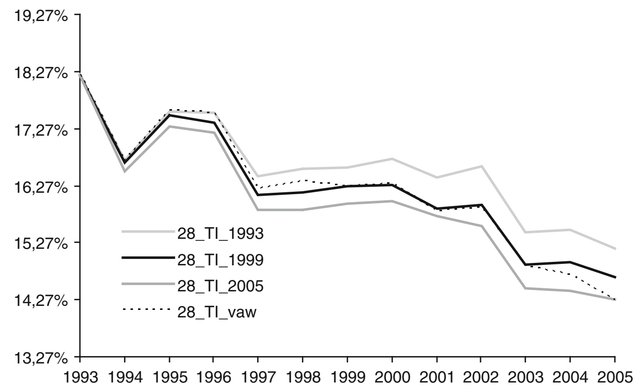

Fig. 4 Chemicals—total inventory to sales ratio 1993–2005

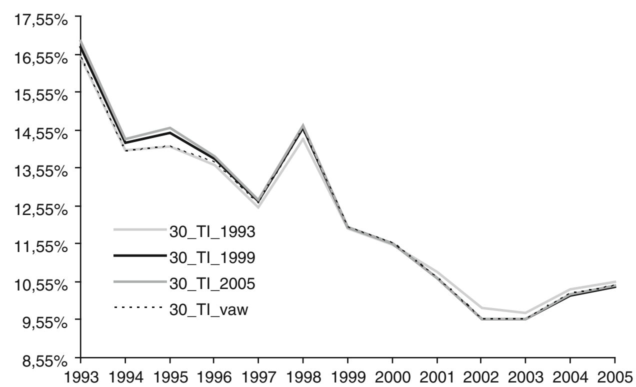

Fig. 5 Rubber and plastics—total inventory to sales ratio 1993–2005

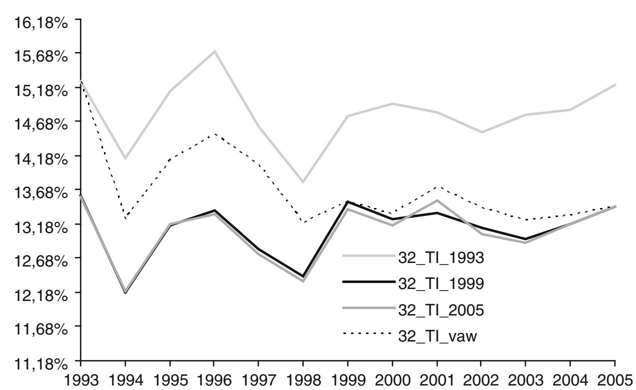

Fig. 6 Stones, clay, and glass—total inventory to sales ratio 1993–2005

which is obviously caused by a sales shift as fixed weighted finished goods, IS ratios discover a constant trend (see. Fig. 7).

The decrease in total IS ratio in the machinery industry becomes significant when using fixed aggregation weights. Using variable weights, we see significant trends in raw

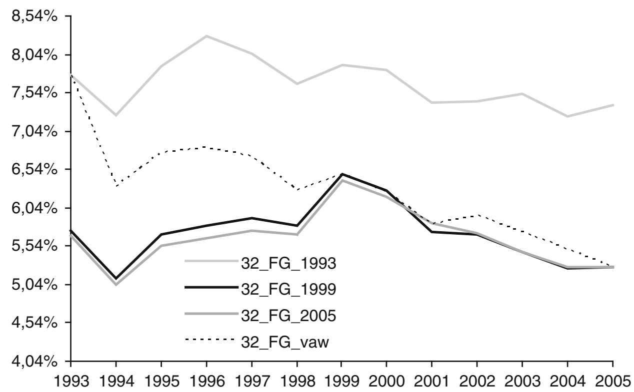

Fig. 7 Stones, clay, and glass—finished goods inventory to sales ratio 1993–2005

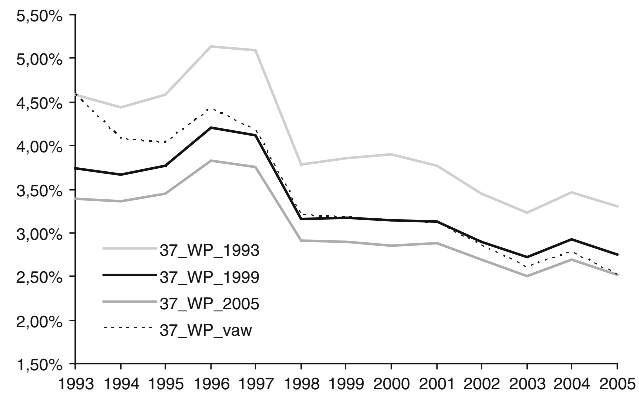

Fig. 8 Transportation equipment—work-in-process inventory to sales ratio 1993–2005

materials and work-in-process IS ratios but in the opposite direction. This observation changes when using fixed weights as the work-in-process decreasing trend remains as a dominant component.[4]

The transportation equipment industry shows no significant results concerning total IS ratios. Digging a bit deeper, we find two interesting effects: (a) significantly decreasing work-in-process IS ratios (see Fig. 8) and (b) sharply increasing finished goods IS ratios in the second half of our time frame investigated (see Fig. 9). These findings hold independent from using fixed or variable weights. In sum, we find a trend break in total IS ratios in the middle of our time frame (see Fig. 10).

Finally, we have to discuss our results for our sample in total where no significant results (with one exception) were found. The reason is easy to explain: there is a trend break in the data (see Fig. 11). In the first (second) half of our time frame, we find decreasing (increasing) finished goods (see Fig. 12) and work-in-process (see Fig. 13) IS ratios. This also holds independent if aggregation was executed from firms or from SIC code classes (sectors), whereas finished goods IS ratios show a constant trend in the second half of the time frame when aggregated from sectors (instead of a slightly increasing trend in the other case) and therefore causing this exception in the data we already mentioned.

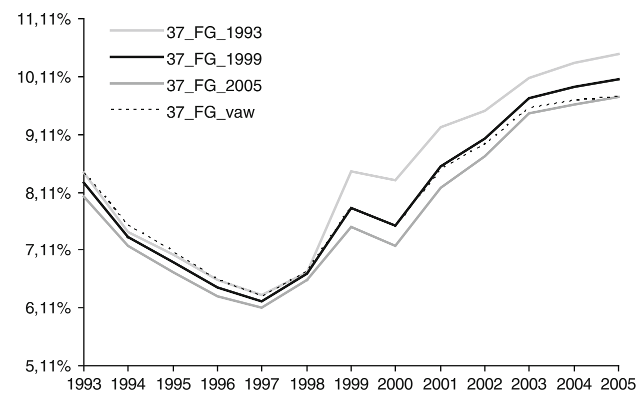

Fig. 9 Transportation equipment—finished goods inventory to sales ratio 1993–2005

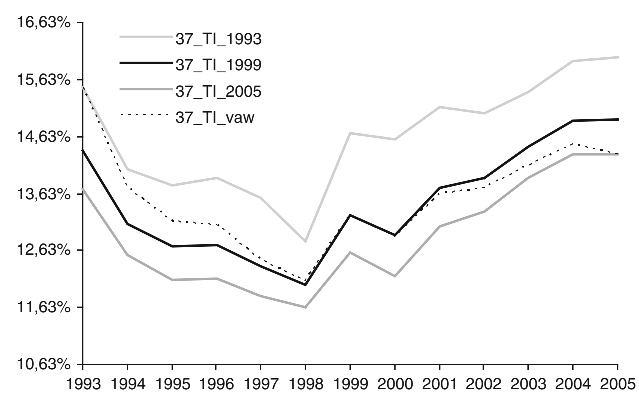

Fig. 10 Transportation equipment—total inventory to sales ratio 1993–2005

In the remaining of this section, we will discuss some implications and limitations linked with the use of fixed aggregated weights for trend analysis. Certain effects that are due to the specific size of our sample as well as its

[4] Nevertheless, it has to be pointed out that within the time frame analyzed, several firms changed from national (according to German Commercial Code, HGB) to International Financial Reporting Standards (IFRS); most of them during the last year investigated. 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 as inventories but accounts receivable. Accordingly, we found evidence for such conversion effects mainly in decreasing work-in-process inventories in the machinery industry. Therefore, this sectors' work-in-process inventory to sales performance has to be interpreted carefully.

composition will be our point of departure, as these effects hold for any other sample with similar characteristics.

In two sector classes (SIC 30 and SIC 36), we find the curve shape of the aggregated IS ratio over time almost congruent with the curve shape of the biggest company (in terms of sales). In both cases, the biggest company contributes by far the lion's share to the sector's total sales volume (Continental AG accounts for 93.43% in SIC 30 and Siemens AG for 95.84% in SIC 36; see also Fig. 14).

Besides this fact, another characteristic typically for sectors with some extraordinary big companies can be identified. From Eq. 4, it can be easily concluded that IS ratios with fixed aggregated weights, no matter what specific year selected, do not remarkably differ from the IS ratio with variable aggregated weights. The closer the value of the fixed term of Eq. 4 for the big company, $S_{i\tau}/\sum_{i=1}^{n} S_{i\tau}$, is to 1, the more the impact of the fixed aggregate weight is extinguished. As a result of this concentration effect, the curve shapes based on fixed aggregation weights are almost congruent to the curve shape of the variable aggregation weights. Because the firm level is almost equal to the industry level, there is not much to be aggregated. For the aggregated total, IS ratio in the electronics and electric equipment industry, for instance, a year's maximal difference between the variable ratio and one of the three fixed weights, amounts to a negligibly small value of 0.11%. In order to isolate this concentration effect, we tentatively removed the top 10% companies per sector in terms of sales from our sample. We will now exemplarily demonstrate this for SIC class 36. If Siemens AG were excluded from the electronics sector, the development of the total IS ratio over time shows especially in the second half of the time frame an overall decreasing trend, instead of an altogether increasing trend (Figs. 14, 15). As expected, Fig. 15 also presents different curve shapes for each of the fixed aggregation weights selected.

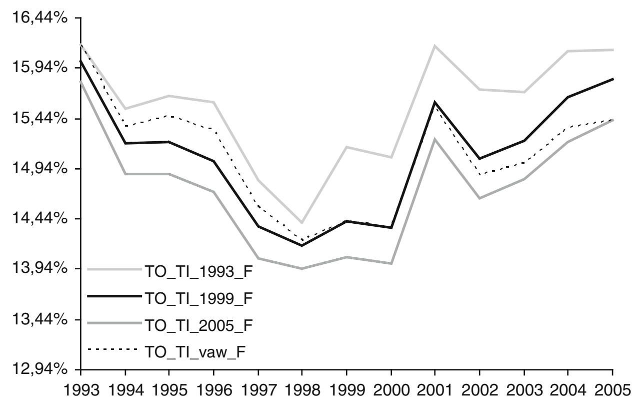

Fig. 11 Total sample (aggregated from firms)—total inventory to sales ratio 1993–2005

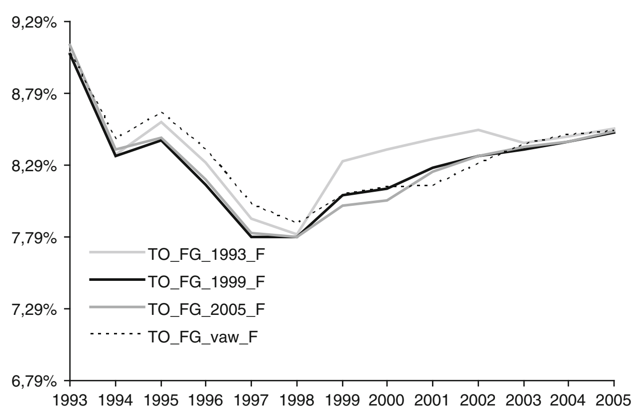

Fig. 12 Total sample (aggregated from firms)—finished goods inventory to sales ratio 1993–2005

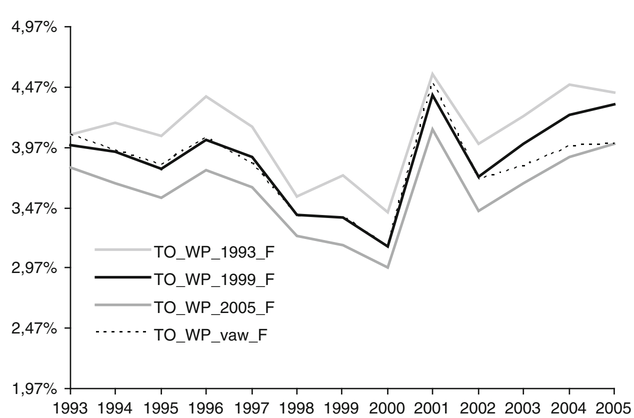

Fig. 13 Total sample (aggregated from firms)—work-in-process inventory to sales ratio 1993–2005

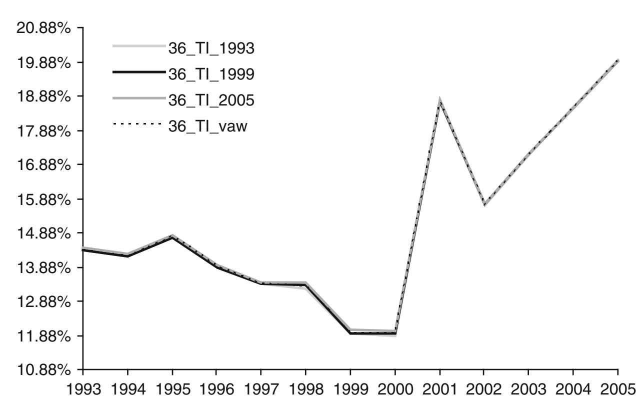

Fig. 14 Electronic and other electric equipment—total inventory to sales ratio 1993–2005

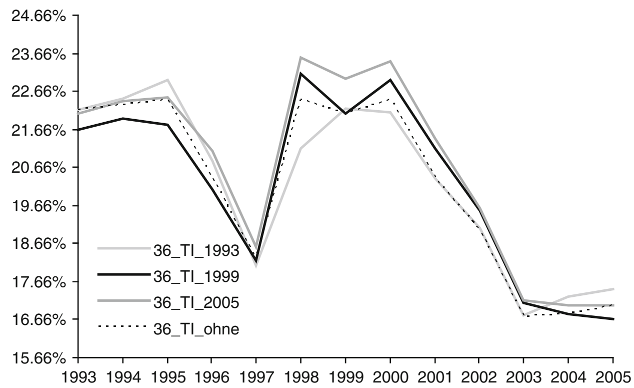

Fig. 15 Electronic and other electric equipment (without Siemens AG)—total inventory to sales ratio 1993–2005

Obviously, the insights deducible from the use of fixed aggregate weights depend to a significant extent on the sales proportion of the biggest firm (subsector) in a specific industry; that is, on the amount of concentration in the sample.

Another interesting aspect is the choice of a specific base year for calculating IS ratios with fixed aggregation weights. If we compare the plots of the IS ratio time series with a fixed weight from the end of the sample (base year 2005) with the ones with a fixed weight from the beginning of the sample (base year 1993), it is quite obvious that in most cases from our sample the two curves run quasi parallel to each other with a distinct spread (see for example Figs. 1, 4, 6–11, and 13 as well as the β-values in Tables 4, 5). For our data sample, the maximum spread reaches an average value of 3.54% (total IS ratios in SIC 20). The reason is that particular firms (subsectors) in our sample exhibit a massive shift in percentage shares of the subsector's (sector's) total sales between the time frame's beginning and the end year. As a consequence, firms (subsectors) with an above subsector (sector) average IS ratio, whose proportion of the aggregated weight increases over the time frame investigated, gain a much stronger impact on the end of sample fixed aggregated weight in comparison with the beginning of sample fixed aggregated weight. Altogether, the result is a higher level of the aggregated IS curve. Firms (subsectors) with a below average IS ratio, on the other hand, cause the aggregated IS curve to run on a lower level. The opposite effect holds for firms (subsectors), whose proportion of the aggregated sales share decreases between the samples' beginning and the end year. The reason for the shift in sales share can be found either in a slight but continuous adjustment over the complete time period investigated, for example, some industries are hit harder than others by economic downturns, or in a one time shift, for example, associated with merger and acquisition activities. The plots of the curve with the time frame's midpoint as base year may give a clue for the shift (see e.g. Fig. 10). The fact, that the fixed aggregated IS ratio curve with base year 1999 runs in between the curves with base year 1993 and 2005, may indicate a slight but continuous adjustment. This effect is exemplarily demonstrated for the aggregated total IS ratio of SIC 35. In the base year 1993, Gea Group AG (average total sales to inventory ratio: 10.62%) accounts for 44.66% of the industry's total sales volume, while Rheinmetall AG (average total sales to inventory ratio: 20.28%) and Salzgitter AG (average total sales to inventory ratio: 16.82%) account only for 5.37 and 10.07%, respectively.

For the base year 2005, a completely different picture emerges. Gea Group AG only contributes 13.74% to the industry's total sales volume, while Rheinmetall AG and Salzgitter AG have a share of 10.55 and 21.84% of total industry's sales, respectively. Based on these companies' shift in the percentage shares of the industry's sales volume as well as their different total IS ratio levels, it can be concluded that the total IS ratio curve for the base year 2005 runs on a higher level than the IS ratio curve for the base year 1993 (see also Fig. 16).

Taking a closer look at the β-values in Tables 4, 5 one finds that the slopes of the IS ratio curves with fixed aggregated weights are often just a fraction of its counterparts with variable aggregated weights (e.g. TI, WP and FG of SIC 20 or RM of SIC 22/23). The answer to this effect goes along with the above-mentioned spread of the quasi parallel curves for the fixed IS ratios with different base years. The variable aggregated weight curve bridges—metaphorically speaking—the spread between the two base year curves over the time frame investigated (as revealed by the plots in Fig. 1), as the fixed IS ratio for a certain base year must correspond with the base years' variable IS ratio (see Eq. 4). This explains the stronger

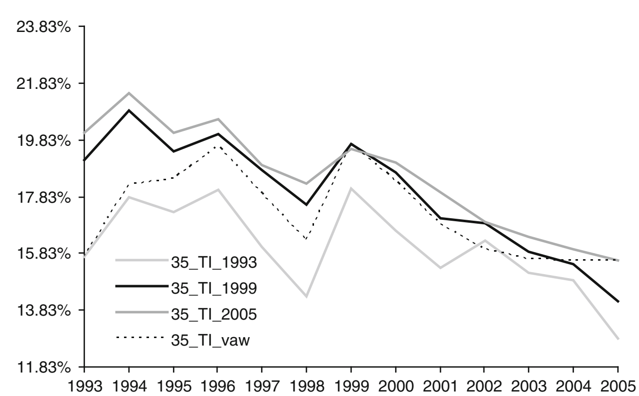

Fig. 16 Industrial machinery and equipment—total inventory to sales ratio 1993–2005

decrease or increase compared to its corresponding fixed IS ratio curves. As a second result, we find that the varying levels of the fixed aggregated IS ratio curves for the different base years are caused by noticeable shifts in sales shares of certain firms (subsectors) within a specific subsector (sector) leading to shifts in the composition of the aggregated weight.

Comparing the β-values underlines the effect resulting from the use of variable aggregated weights and simultaneously raises the question of the adequate base year for the fixed weights. This question is a tough one and seems to allow for no general answer. To a certain extent, we do agree with Irvine's [13] findings, as the shifts in the composition of several aggregated weights in our sample clearly demonstrate that fixed weights tend to be overstated in periods before the base year and understated in periods after the base year. We do also share Irvine's [13] recommendation to use end of sample fixed weights if a specific observed trend in the aggregate IS ratio, relevant to the current composition of firms (subsectors) making up the aggregate, should be assured (e.g. forecasting purposes). But choosing the midpoint of a sample as base year, as Irvine [[13], p. 49, fn. 5] proposes for a particular historical period, for example, from 1993 to 2005, reveals a somewhat mixed picture and may be a much too global approach, as can be demonstrated by means of our sample data. In some cases, the curve with base year 1999 is plotted right in between the beginning and the end base year curves. This may indicate a slightly but continuous shift from the aggregated IS ratio curve running on a higher (lower) level to the aggregated IS ratio curve running on a lower (higher) level during the time frame observed (e.g. RM IS ratio for SIC 22/23 or FG IS ratio for SIC 28). In this case, the period's midpoint may be a good selection for the base year. But in the majority of cases, the fixed aggregated IS ratio curve for the midterm base year has an almost identical shape and level like one of the other base year's curves, which questions the selection of the time frame's midpoint as an appropriate base year. For us, it seems that if the effect researchers are focused on is believed to show a stronger manifestation in the beginning of the time frame, it may be a reasonable approach to use the sample's first year as base year for the fixed aggregated weights. To a certain extent, this selection may also help to absorb the impact of emerging trends during the time frame that could intermingle with the effects actually accounted for.

4 Conclusion

This study is aimed at analyzing the difference in using fixed weight aggregate IS ratios rather than "traditional", that is, variable weighted, aggregated IS ratios. After illustrating the implications of these methods, we applied them on empirical data of IS ratios of German firms. We show that difficulties arise because different aggregation methods are signaling different time trends under certain circumstances. Analyzing the inventory performance of 100 German corporations between 1993 and 2005, our findings indicate that the total IS ratio decreased in a statistically significant extent in the majority of industry sectors during the time frame investigated. Regarding our results on an aggregated level based on variable weights, we find remarkably decreasing total IS ratios in different sectors. The results for our sample in total show a trend break in the data. In the first (second) half of our time frame, we find decreasing (increasing) IS ratios. Considering the effects of using fixed aggregation weights on our results, some changes concerning significance of results occur. The use of fixed aggregation weights in addition to variable aggregation weights is helpful because it isolates any trends observed in the aggregated IS ratio series to fluctuations in the underlying (sub) sectors' IS ratios, not shifts in the composition of the aggregate. Nevertheless, we also discussed some implications and limitations that are linked with fixed aggregation weights, whereas the question for an adequate base year offers an interesting starting point for further research.

Appendix

See Table 6.

Table 6 Sample formation and descriptive measures

Nr.	SIC	Firm	TI			RM			WP			FG			Proportion of total sector sales (%)
			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	20.83
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	2.25
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	12.95
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	2.41
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	0.28
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	3.08
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	1.94
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	1.86
11	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	45.99
9	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	2.03
10	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	0.13
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	6.24
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	3.10
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	0.10
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	2.11
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	3.17
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	0.19
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	52.33
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	3.47
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	7.93
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	0.47
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	3.32
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	0.46
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	3.54
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	9.33
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	7.51
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	2.96
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	2.06
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	31.88
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	28.15
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	3.94
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	0.21

Table 6 continued

Nr.	SIC	Firm	TI			RM			WP			FG			Proportion of total sector sales (%)
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	
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	4.98
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	0.92
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	10.58
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	7.10
37	28	Merck KGaG	19.69	19.44	11.87	4.22	4.30	20.57	0.00	0.00	n. def.	15.48	15.14	10.43	5.38
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	0.74
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	4.05
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	93.43
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	1.06
42	30	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	1.40
43	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	0.31
44	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	1.78
45	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	2.01
46	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	1.16
47	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	5.28
48	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	14.33
49	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	0.83
50	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	45.94
51	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	1.28
52	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	4.92
53	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	1.62
54	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	3.26
55	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	8.87
56	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	4.38
57	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	0.37
58	32	Villeroy & 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	7.76
59	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	0.08
60	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	0.32
61	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	4.49
62	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	0.53
63	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	4.47

Table 6 continued

Nr.	SIC	Firm	TI			RM			WP			FG			Proportion of total sector sales (%)
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	
64	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	26.90
65	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	2.24
66	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	1.19
67	35	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	0.28
68	35	Jungheinrich 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	4.25
69	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	5.83
70	35	Koenig & 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	3.26
71	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	3.44
72	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	3.63
73	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	5.45
74	35	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	5.21
75	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	10.75
76	35	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	13.18
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	1.05
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	1.74
79	35	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	1.72
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	0.11
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	0.31
82	36	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	1.61
83	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	0.41
84	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	0.11
85	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	0.12
86	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	0.04
87	36	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	95.84
88	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	0.46
89	36	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	0.97
90	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	11.76
91	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	0.10
92	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	24.12
93	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	0.29
94	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	9.35
95	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	2.46
96	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	0.10

Table 6 continued

Nr.	SIC	Firm	TI			RM			WP			FG			Proportion of total sector sales (%)
			Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	Mean (%)	Median (%)	Varc (%)	
97	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	0.21
98	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	0.14
99	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	51.24
100	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	0.24

Source: [16] with own calculations

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