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Have U.S. Manufacturing Inventories Really Decreased? An Empirical Study

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Numerous normative models have been developed to determine optimal inventory levels, and several articles and case studies have been written about the concerted efforts and practices adopted by manufacturing firms in the United States to reduce inventories. But little is known about whether inventories have indeed decreased in U.S. manufacturing and whether such a decrease has been restricted to a few well-publicized firms or is true at an industry level. Using data published by the U.S. Census Bureau, the authors study trends in materials, work-in-process, and finished-goods inventory ratios during the period 1961 to 1994 in 20 manufacturing industry sectors and the total U.S. manufacturing sector to determine whether a significant decrease was seen in these ratios. Further, since a great deal of momentum for inventory reduction began in the early 1980s, the authors investigate whether greater improvement was seen in the post-1980 period as compared with the pre-1980 period. We find that material and work-in-process inventories did decrease in a majority of the two-digit industry sectors from 1961 to 1994 and showed greater improvement in about half the sectors in the post-1980 period relative to the pre-1980 period. Finished-goods inventories did decrease in some industry sectors and increase in a few others but did not show a significant trend in more than half the sectors. Total manufacturing inventory ratios decreased from 1961 to 1994 at all three stages—material, work-in-process, and finished goods. However, total manufacturing inventory ratios did not improve at a higher rate during the post-1980 period as compared with the pre-1980 period in any of the three stages. Overall, the analysis provides an encouraging but somewhat mixed picture about the results of U.S. manufacturing inventory-reduction efforts.

(*Manufacturing; Inventory; Empirical Study; Time Series*)

1. Introduction

This research is motivated by the lack of definitive answers in the literature to the following set of important questions: Has there been a decrease in overall U.S. manufacturing inventories during the past four decades? If so, then (1) has the decrease been faster since the early ’80s, when, according to the business press, just-in-time (JIT), inventory reduction, and so forth have been the focus of management attention? (2) Has the decrease been limited to some sectors of manufacturing and not to the others? (3) Where has this decrease occurred: materials-and-supplies, work-in-process, or finished-goods inventories? We provide answers to these questions using aggregate industry-level data published by the U.S. Census Bureau.

The past four decades have seen several innovations with potentially positive impact on inventories—developments in inventory theory and their application, process innovations such as MRP, just-in-time, cycle time reduction, quick response, and development of

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technologies such as bar-coding, automated warehousing, and information technologies. Several articles have appeared in the popular press (*Fortune* 1984, *Business Week* 1984) on the benefits realized from adopting these innovations. Several books and articles have presented case studies of successful implementation of JIT in such U.S. firms as Harley-Davidson and Hewlett-Packard (Schonberger 1986, Sepheri 1986) and the benefits from cycle time reduction and quick response initiatives (Stalk and Hout 1990). A number of industries, such as food and textiles, implemented these approaches and, given the direct relationship between inventories and lead times, one would expect corresponding inventory reductions.

Despite considerable anecdotal evidence and the generally accepted notion that inventories have decreased, only a few empirical studies have examined inventory performance over time in a systematic manner. Billesbach and Hayen (1994) studied the long-term impact of JIT on inventory performance measures in 27 financially successful firms. Chang and Lee (1995) compared firms implementing JIT with firms not implementing it to show that JIT firms improved inventory turnover but did not achieve better performance on other financial measures. Huson and Nanda (1995) found that firms adopting JIT reduced labor content, increased inventory turnover, and improved earnings.

Although these empirical studies provide evidence in support of the notion that JIT has improved inventory performance, they are limited to firms in a few industries and so may have limited generalizability. For example, the Chang and Lee study had about 44 firms each in the JIT and non-JIT categories and 75% of the firms in the JIT group were in three industries: machinery, transportation equipment, and instruments. The Huson and Nanda study had 55 firms and about 75% of them were in the three industries mentioned earlier and electronic equipment. Also, those studies focused on inventory performance in the 1980s and early 1990s.

This study, to our knowledge, is the first one to comprehensively investigate inventory trends since the early 1960s in all the manufacturing sectors and at all stages of manufacturing, i.e., material, work-in-process, and finished goods. We also study whether the post-1980 period showed greater improvement than the pre-1980 period as suggested by anecdotal evidence.

The rest of the article is organized as follows: In the next section, we present the research methodology employed and several hypotheses regarding inventory trends in recent years as compared with trends in the 1960s and 1970s. We also describe the data sources used. We present our findings in §3 and discuss their implications in §4. We conclude in §5 with limitations of our study and other remarks.

2. Research Methodology

The questions posed in §1 can be studied at a firm or industry level. A firm-level analysis, with firms selected randomly, is not feasible for studying inventories at all manufacturing stages because firms are not required to report inventories by stage of manufacturing and many do not.

We also did not pursue the approach of categorizing firms into two groups, adopting or not adopting JIT or other inventory-reduction strategies, for several reasons. First, our interest is in finding out whether inventory reduction occurred at an industry level rather than at a few well-known firms. Second, firms implement such methods to varying degrees of commitment, making it difficult to categorize them into only two groups. Finally, the focus here is not on the specific causes of inventory reduction such as JIT or quick-response implementation.

The industry analysis could have been done at any level of aggregation, two- or three- or four-digit SIC code. We used the two-digit level comprising 20 sectors for two reasons. First, firms and industry subsectors at three- and four-digit levels are periodically moved from one subsector to another, and this would adversely impact the accuracy of the analysis. This effect is less likely at the two-digit level. The second reason for performing the analysis at the two-digit level was brevity and ease of exposition. Some drawbacks of analysis at the two-digit level will be discussed in §5.

To evaluate inventory performance over time, it is inappropriate to simply use inventory in dollar values because inventory levels vary with output levels,

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which vary with time. So, inventory may decrease in an industry simply because output decreased. Therefore, we use the following inventory ratios, which are similar to those used in prior empirical studies (Huson and Nanda 1995) and reported in industry publications (Dun and Bradstreet 1995). Similar ratios are used commonly in industry to evaluate the inventory performance of a firm. Detailed definitions of the variables and data sources used in computing the ratios below are in Appendix 1.

Inventory type	Inventory ratio measure used in study
Materials and Supplies	$\dfrac{\textit{Materials-and-Supplies Inventory}}{\textit{Material cost}}$
Work-in-process	$\dfrac{\textit{Work-in-process Inventory}}{\textit{Material cost} + 0.5^{*}\textit{Value added}}$
Finished Goods	$\dfrac{\textit{Finished-goods Inventory}}{\textit{Material cost} + \textit{Value added}}$

We studied inventory ratios separately at the three stages of manufacturing (materials-and-supplies, work-in-process, and finished goods) for two reasons. First, inventories are typically classified in this manner, and the ratios recognize the fact that inventories are valued differently at the three stages; therefore, it is useful to understand the extent of improvement in inventory performance at each of the three stages. Second, as the extent of vertical integration or outsourcing of operations in a firm or industry sector changes, total inventory levels may not change but the composition of inventories by stage of manufacturing may change. For example, an increase in outsourcing is likely to result in higher material inventories and material costs and lower work-in-process inventories and value added.

An important advantage of these ratios is that the analysis is not dramatically affected by changes in price levels of raw materials, component parts, and finished goods that affect the value of the inventory. Also, these ratios compensate for the impact of change in the value of a dollar over the years.

Although there may be differences among industry sectors in the valuation of inventories, this is unlikely to affect our analysis and conclusions because the focus is on comparing change in inventory ratios over time in the same sector rather than comparing ratios across sectors. Also, our choice of the coefficient 0.5 in computing WIP ratios is quite arbitrary, although it is commonly used. However, the exact value of this coefficient is not likely to affect our results/conclusions significantly because we are using the same weight in all years and are making comparisons over time within an industry rather than across sectors. For similar reasons, our use of value of output or value of shipments (= value added + material cost) rather than cost of goods sold, data on which are not available from the U.S. Census Bureau, in computing the inventory ratios should not affect materially the results and conclusions stated here.

Cutoff Date

Anecdotal evidence suggests that inventory reduction became a significant crusade in the United States during the late 1970s and 1980s with slogans such as "zero inventory" and "inventory is evil" used frequently and JIT production credited with most of the inventory-reduction benefits. We did an exhaustive search using large databases of articles in the popular press (Lexis-Nexis 1996) and the academic literature (ABI/INFORM 1996). The earliest references to use of JIT production in the United States appear to be around 1980–1981 (Hayes 1981), although a few U.S. plants (primarily Japanese owned) implemented JIT methods in the late 1970s (Schonberger 1982). Also, Chang and Lee (1995) and Huson and Nanda (1995) use 1980 as a start date in their studies of JIT adoption, with 95% of the firms in their studies adopting JIT in or after 1980. Finally, Schonberger (1986, p. 3) refers to 1980 as a "turning point" in the implementation of JIT in U.S. plants. So, we used 1980 as the cutoff date; i.e., we investigated whether the pre-1980 period showed greater improvement in inventory ratios as compared to the post-1980 period.

Regression Model

We used a simple linear regression model with time or year as an independent variable to investigate the rate of change in inventory ratios over time. Theory and anecdotal evidence suggest that inventory ratios may be influenced by business cycles. Preliminary analysis indicated that variables such as GDP growth did not add any significant predictive value in individual industry sectors. So, instead, we used growth in the

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value of output in each sector as a control variable. We used the following model for each of the three inventory ratios for the 20 industry sectors and the total U.S. manufacturing sector to assess overall trends from 1960 through 1994.

$$\text{Inventory ratio} = \beta_{01} + \beta_{11}T + \beta_{21}g, \qquad (1)$$

where T represents the year, g the growth in output in a sector, β_{01} the intercept, β_{11} the trend coefficient, and β_{21} the coefficient of the variable g. The variable g is measured as the percentage change in the value of shipments or output in a sector from year $(T - 1)$ to T.

We are also interested in finding out whether inventories have been decreasing at a higher rate during the period 1980–1994 as compared with the pre-1980 period. As the number of data points in the second period is small, we used a dummy-variables model to study the difference in trends (Kennedy 1992). The regression model used to determine this difference is

$$\text{Inventory ratio} = \beta_{02} + \beta_{12}T + \beta_{22}(T - T_0)X + \beta_{32}g, \qquad (2)$$

where T is time with T_0 as 1980, and $X = 1$ if $T > T_0$ or $X = 0$ if $T \leq T_0$. Here β_{12} measures the slope over the period (1961–1980) and β_{22} measures the difference in slope between the periods 1980–1994 and the period 1961–1980. Thus, the hypothesis test on whether the inventory trend during the period 1980–1994 is different from the trend in the pre-1980 period is on β_{22}. The advantage of this model is that all the data are used to estimate the coefficient so the degrees of freedom are larger and the test is a stronger one (Kennedy 1992).

As we used time-series data, we checked for serial correlation of the residuals using the Durbin-Watson test. In most cases, there was evidence of autocorrelation; therefore, we used the Cochrane-Orcutt procedure to estimate the coefficients in Equations (1) and (2). The Cochrane-Orcutt procedure helps in determining consistent estimates of the regression parameters (Neter, Wasserman, and Kuttner 1983, Kennedy 1992).

Hypotheses

The objective of the research is to test anecdotal evidence and the generally accepted notion that adoption of modern inventory practices has decreased inventories in U.S. manufacturing. Even if JIT-type practices are not adopted, inventory theory suggests that inventory ratios should decrease with an increase in output (due to the "square root" formulas such as the EOQ formula) if product variety is unchanged. Implementing such inventory models is in itself an example of adopting leading edge inventory practices. However, there are other factors that may result in *increasing* inventory ratios. For example, increase in product variety, number of plant and warehouse locations, and more make-to-stock production can increase inventories. Similarly, increase in the number of suppliers or increased imports can result in higher material inventories. Despite these factors, most articles in both the business press and the academic literature have claimed that inventories have decreased in U.S. manufacturing. Therefore, the hypotheses that follow are stated in terms of decrease in inventories.

Anecdotal evidence suggests that adoption of process improvements or technologies may be restricted to a few industry sectors. For instance, most of the major JIT success stories reported are in transportation, equipment manufacturing, and electronics (Sepheri 1986). There have been few references to JIT adoption in industries such as food, lumber, or furniture. However, there have been articles recently on the adoption of quick response systems and cycle time reduction in industries such as food and apparel (Rice 1994, Nannery 1996). An exhaustive keyword search using the Lexis-Nexis (1996) database to analyze the number of citations of process improvements such as JIT and cycle time reduction did not yield any clear differences across industry sectors. Therefore, there is no *a priori* reason to believe that inventory reduction did not take place in certain industry sectors; our first hypothesis is

HYPOTHESIS 1. *In each of the 20 industry sectors, designated by SIC codes 20 through 39:*

(a) *Inventory ratios will show a decreasing trend from 1961 to 1994, i.e.,* β_{11} *(1961–1994)* < 0*;*

(b) *Inventory ratios will show a higher rate of improvement in the 1980–1994 period compared with the pre-1980 period, i.e.,* β_{22} *(1980–1994)* < 0*.*

Although individual industry sectors may have shown varying levels of improvement in inventory practices and ratios, an important question is whether there has been an overall improvement in inventory

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ratios for the total U.S. manufacturing sector. So, we have

Hypothesis 2. *For the total manufacturing sector in the United States:*

(a) *Inventory ratios in each sector will show a decreasing trend during the period 1961–1994, i.e., β_{11}(1961–1994) < 0;*

(b) *Inventory ratios will show a higher rate of improvement in the 1980–1994 period compared with the pre-1980 period, i.e., β_{22} (1980–1994) < 0.*

The nature of various stages of inventory is such that the rate of improvement may differ across stages in the different sectors. But the focus of process improvements such as just-in-time and cycle time reduction has been on reducing work-in-process inventory. Clearly, these initiatives would also reduce finished-goods inventory due to Little's law and also possibly materials inventories, but may have a larger effect on work-in-process inventory. Also, work-in-process inventory is more dependent on factors within a firm's control relative to material and finished-goods inventories. So, we have

Hypothesis 3. *During 1960–1994, in each of the 20 sectors and the total manufacturing sector,*

(a) *work-in-process inventory ratios will show a higher rate of improvement than materials-and-supplies inventory ratios, β_{11}(WIP) $< \beta_{11}$(Materials and Supplies);*

(b) *work-in-process inventory ratios will show a higher rate of improvement than finished-goods inventory ratios, β_{11}(WIP) $< \beta_{11}$(Finished Goods).*

To test Hypotheses 1 and 2, we used ordinary least-squares regression, together with the Cochrane-Orcutt procedure when residuals had significant serial correlation, to estimate the coefficients β_{01}, β_{11}, and β_{21} in (1) and β_{02}, β_{12}, β_{22}, and β_{32} in (2) for various inventory types and industry sectors. To test Hypothesis 3, we used the β_{11} coefficient in (1) and conducted a t test to check for differences in trend coefficients (Kennedy 1992).

3. Results

The inventory ratios for the 20 sectors and total manufacturing for the years 1961, 1980, and 1994 are given in Table 1. The raw numbers in Table 1 indicate that inventory ratios at all three stages of manufacturing in most sectors are lower in 1994, relative to both 1961 and 1980. Clearly, this does not imply that inventories have been consistently *decreasing* over time in all these cases. So, we now provide regression results (Tables 2 and 3) to test the hypotheses.

Analysis by Sectors

Materials-and-Supplies Inventory. Looking at the coefficients for time (T) in Table 2, Hypothesis 1(a) was supported in 12 sectors, confirming a significant decreasing trend from 1961 to 1994. There was no pattern to this decrease among the sectors—a decreasing trend was evident in both primary sectors such as lumber/wood as well as sectors such as furniture/fixtures. Hypothesis 1(b) was supported in 7 sectors (refer to Table 3), i.e., the ratios exhibited a higher rate of improvement in the pre-1980 period than in the post-1980 period (in addition, the hypothesis was supported in the instruments sector at the 0.1 level). Only 2 sectors (apparel and electric/electronic equipment) showed a significant, *increasing* trend from 1961 to 1994. Only 1 sector (petroleum) showed a worsening trend post-1980 relative to pre-1980.

Work-in-Process Inventory. Hypothesis 1(a), confirming a significant decreasing trend during 1961–1994, was supported in 11 sectors (Table 2). Hypothesis 1(b), indicating greater improvement in inventory ratios in the post-1980 era relative to the pre-1980 era, was supported in 9 sectors (Table 3). Seven of the 11 sectors that showed a significant decreasing trend over the 1961–1994 period also showed a higher rate of improvement in the 1980–1994 period. Three sectors (food, apparel, and leather/leather products) showed a significant increasing trend in inventory ratios from 1961–1994. Again, petroleum was the only sector to show a worsening trend during 1980–1994 as compared to the pre-1980 period.

Finished-Goods Inventory. Hypothesis 1(a) was supported in 6 sectors (in 2 other sectors, printing and machinery, the hypothesis was supported at the 0.1 level), but Hypothesis 1(b) was supported in only 3 sectors (in the machinery sector, the hypothesis was

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Table 1 Inventory Ratios

	Materials and Supplies			Work-in-Process			Finished Goods		
Industry sector	1961	1980	1994	1961	1980	1994	1961	1980	1994
Food and kindred products	0.049	0.047	0.043	0.007	0.011	0.013	0.053	0.045	0.039
Tobacco products	0.820	0.578	0.619	0.007	0.014	0.012	0.022	0.018	0.030
Textile mill products	0.100	0.077	0.063	0.055	0.054	0.040	0.063	0.047	0.050
Apparel, other textile products	0.074	0.106	0.117	0.029	0.040	0.037	0.050	0.060	0.061
Lumber and wood products	0.087	0.084	0.072	0.038	0.032	0.024	0.067	0.049	0.034
Furniture and fixtures	0.132	0.147	0.116	0.042	0.052	0.033	0.041	0.047	0.045
Paper and allied products	0.109	0.097	0.093	0.016	0.015	0.012	0.034	0.036	0.037
Printing and publishing	0.090	0.106	0.082	0.024	0.025	0.022	0.022	0.025	0.029
Chemicals, allied products	0.103	0.089	0.083	0.025	0.026	0.025	0.064	0.052	0.054
Petroleum and coal products	0.027	0.014	0.030	0.024	0.015	0.018	0.061	0.023	0.034
Rubber, miscellaneous plastics	0.082	0.096	0.089	0.026	0.029	0.019	0.072	0.054	0.047
Leather, leather products	0.101	0.102	0.102	0.047	0.043	0.046	0.051	0.059	0.071
Stone, clay, glass products	0.102	0.098	0.082	0.023	0.023	0.020	0.068	0.061	0.057
Primary metal industries	0.138	0.102	0.077	0.077	0.078	0.063	0.057	0.043	0.042
Fabricated metal products	0.124	0.126	0.102	0.071	0.078	0.052	0.047	0.042	0.042
Machinery, except electric	0.131	0.134	0.104	0.134	0.136	0.084	0.071	0.061	0.048
Electric, electronic equipment	0.109	0.134	0.109	0.111	0.132	0.102	0.050	0.040	0.033
Transportation equipment	0.062	0.081	0.047	0.100	0.143	0.112	0.016	0.023	0.016
Instruments, related products	0.124	0.172	0.157	0.138	0.124	0.054	0.047	0.047	0.043
Misc. manufacturing industries	0.173	0.138	0.136	0.137	0.059	0.044	0.074	0.071	0.075
Manufacturing sector	0.096	0.084	0.078	0.055	0.061	0.051	0.049	0.042	0.039

supported at the 0.1 level). Furthermore, 4 sectors actually showed a significant increasing trend from 1961–1994, and 3 sectors showed a significant worsening trend in inventory ratios during 1980–1994 as compared with 1961–1980.

Total U.S. Manufacturing

Hypothesis 2(a) was supported at all three stages—materials, work-in-process, and finished goods (Table 2, last row). Hypothesis 2(b) was not supported at any stage (Table 3, last row).

WIP Versus Materials and Finished Goods

The last two columns in Table 2 compare the coefficients of work-in-process inventory trends during 1961–1994 with the coefficients of materials/supplies and finished-goods inventory trends. A large negative value of the t statistic indicates support of Hypotheses 3(a) and 3(b), implying that work-in-process inventory ratios showed a greater rate of improvement from 1961–1994 than material or finished-good inventory ratios. We find that Hypothesis 3(a) was *not supported* in 19 of the 20 sectors (except for electric/electronic equipment) nor in the case of total U.S. manufacturing. Hypothesis 3(b) was supported only in 3 industry sectors (the hypothesis is supported in the machinery sector at the 0.1 level), i.e., work-in-process inventory ratio showed a higher rate of improvement than finished-goods inventory ratio during 1961–1994. Finally, Hypothesis 3(b) was supported in the case of total U.S. manufacturing.

Impact of Growth in Output (g)

Although the focus of this study is not on the impact of output growth on inventory ratios, theory tells us that inventory ratios should be negatively correlated with growth rates. When output growth is high, inventories get depleted and there is a lag before production catches up with demand, and so inventory ratios are low and vice versa. Indeed, the regression

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Table 2 Overall Trend Coefficient (1961–1994)

		Regression coefficients 1961–1994 (β_{11}, and β_{21})			Difference in trend Coefficient (t statistic)	
Sector	Variable	Materials and Supplies	Work-in-Process	Finished Goods	WIP vs. Mat.	WIP vs. FG
Food and kindred products	Time (T)	−0.002570***	0.000170***	−0.000539***	23.249***	10.985***
	Growth rate (g)	−0.009200	0.004600	−0.009000		
Tobacco products	Time (T)	−0.0026	0.000042	0.000517**	0.0217	−0.226
	Growth rate (g)	−0.288****	0.002700	−0.012		
Textile mill products	Time (T)	−0.000886***	−0.000521***	−0.000362**	0.678	−0.686
	Growth rate (g)	0.006000	−0.011000	−0.015700*		
Apparel, other textile products	Time (T)	0.000243**	0.000250**	0.000160**	0.012	0.486
	Growth rate (g)	0.046000	0.016000	−0.007000		
Lumber and wood products	Time (T)	−0.000283**	−0.000284***	−0.000426*	0.006	0.317
	Growth rate (g)	−0.002700	−0.006800	−0.015800*		
Furniture and fixtures	Time (T)	−0.001174***	−0.001116***	0.000044	0.0337	−4.3306***
	Growth rate (g)	0.005700	0.009000	−0.0109		
Paper and allied products	Time (T)	−0.000120***	−0.000133***	0.000024	−0.072	−2.554**
	Growth rate (g)	0.023000	0.000280	−0.017000***		
Printing and publishing	Time (T)	−0.000345***	−0.000330***	−0.000128	0.0048	−0.7988
	Growth rate (g)	0.028000	0.010000	−0.012		
Chemicals, allied products	Time (T)	−0.000005**	−0.000019	−0.000137	−0.02	0.0342
	Growth rate (g)	0.019000	−0.007590*	−0.016000****		
Petroleum and coal products	Time (T)	−0.000052	−0.000133*	−0.000639*	−0.201	1.308****
	Growth rate (g)	−0.008500*	−0.003700	−0.002500		
Rubber, miscellaneous plastics	Time (T)	−0.000272***	−0.000267***	−0.000590***	−0.4699	1.33****
	Growth rate (g)	0.014000	0.000002	−0.021000**		
Leather, leather products	Time (T)	0.000097	0.000269***	0.000819***	0.192	−1.029
	Growth rate (g)	0.014000	−0.001600	−0.020000		
Stone, clay, glass products	Time (T)	−0.001615	−0.000749	0.000283	0.951	−0.003
	Growth rate (g)	−0.006600	−0.011000	0.046000		
Primary metal industries	Time (T)	−0.000962	0.000004	−0.000037	0.4448	0.025
	Growth rate (g)	−0.039000***	−0.030000***	−0.032000***		
Fabricated metal products	Time (T)	−0.000747*	−0.000872*	0.000094	−0.0169	−2.039*
	Growth rate (g)	0.063000	0.005900	−0.026000***		
Machinery, except electric	Time (T)	−0.002400***	−0.002300***	−0.000456*	0.0446	−1.435****
	Growth rate (g)	0.022000	−0.013000	−0.039000***		
Electric, electronic equipment	Time (T)	0.013197*	0.000041	−0.000479***	−2.813**	0.167
	Growth rate (g)	−0.049000	−0.113000**	−0.010000*		
Transportation equipment	Time (T)	−0.000662	0.002400****	0.000360*	0.4068	0.2719
	Growth rate (g)	0.008000***	−0.039000***	−0.013700***		
Instruments, related products	Time (T)	−0.002153*	−0.002014*	−0.000171	0.0301	−0.728
	Growth rate (g)	0.103000	0.066000	−0.007000		
Misc. manufacturing industries	Time (T)	−0.000881**	−0.000856**	0.000071	0.0026	−0.2662
	Growth rate (g)	0.014000	−0.002900	−0.015700		
Manufacturing sector	Time (T)	−0.000479***	−0.000573*	−0.000227***	−0.2444	−1.77*
	Growth rate (g)	−0.001580	−0.025000***	−0.024000***		

*0.05 level. **0.01 level. ***0.001 level. ****0.1 level.

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Table 3 Difference in Trend Coefficients Post-1980 and Pre-1980

	Difference in trend coefficient between post-1980 and pre-1980 periods (β_{22})		
	Materials and Supplies	Work-in-Process	Finished Goods
Food and kindred products	0.000183	−0.000040	0.000138
Tobacco products	−0.002940	−0.000199	−0.000317
Textile mill products	−0.00037	−0.00074**	0.001010**
Apparel, other textile products	−0.000400	−0.000777***	−0.000560**
Lumber and wood products	−0.018740	−0.000355	−0.006790
Furniture and fixtures	0.003990**	−0.001925***	−0.00091**
Paper and allied products	−0.000205	−0.000176*	0.000054
Printing and publishing	−0.003874***	−0.000044	0.000625*
Chemicals, allied products	0.000430	−0.000145	−0.000094
Petroleum and coal products	0.001780***	0.000550***	0.003080***
Rubber, miscellaneous plastics	−0.001687*	−0.000589***	0.000087
Leather, leather products	−0.000626*	−0.000053	−0.000471
Stone, clay, glass products	−0.000786	−0.000400	−0.000918
Primary metal industries	−0.002320	−0.002450**	−0.000245
Fabricated metal products	−0.004430*	−0.003170***	−0.000508
Machinery, except electric	−0.003800*	−0.003490**	−0.001460****
Electric, electronic equipment	−0.003351***	−0.000890	−0.000650**
Transportation equipment	−0.002600***	0.000750	−0.000090
Instruments, related products	−0.005690*	−0.007400***	−0.000634
Misc. manufacturing industries	−0.002400	−0.000679	−0.000523
Manufacturing Sector	−0.000615	−0.000450	−0.000325

*0.05 level. **0.01 level. *** 0.001 level. ****0.1 level.

coefficient for growth (Table 2) was negative in most cases. Growth was a significant predictor in as many as 9 sectors for finished-goods inventory ratios, but only in 2 sectors in the case of material inventory ratios, and 4 sectors in the case of work-in-process inventory.

4. Discussion

The results provide an encouraging but somewhat mixed picture of the state of inventory reduction in U.S. manufacturing. Significant progress has been made from 1961 to 1994, as evidenced by the decreasing trend in materials/supplies and work-in-process inventory ratios in a majority of the industry sectors. A decreasing trend was observed in most of the remaining sectors, although the trend was not statistically significant. More promising, these sectoral improvements have translated into a decreasing trend for total U.S. manufacturing inventory ratios at all three stages during 1961–1994. However, while inventory ratios have been decreasing, finished-goods inventory ratios have not shown as much improvement as materials or work-in-process inventory ratios during 1961–1994 or in the post-1980 period relative to the pre-1980 period. Anecdotal evidence about major inventory reductions in the post-1980 period was supported in fewer than half the sectors. Also, the three inventory ratios for the total manufacturing sector have not shown significantly greater improvement in the post-1980 period relative to the pre-1980 period.

Several other interesting points emerge from the analysis. First, industry sectors such as textiles, lumber, printing/publishing, rubber, and machinery showed improvement in inventory ratios at all three stages of manufacturing. Further, other sectors such as furniture and fabricated metal products showed improvement

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in both materials/supplies and work-in-process inventory ratios. Most of these industry sectors also showed greater improvement in the 1980–1994 period.

Second, several case studies and empirical studies on JIT adoption have focused on the benefits derived in electric/electronic equipment and transportation equipment sectors. However, we do not find convincing evidence of this over the 1961–1994 period in either sector. However, materials and finished-goods inventory ratios in electric/electronic equipment and materials inventory ratios in transportation equipment did decrease at a higher rate in the post-1980 period.

Finally, the number of sectors showing a decreasing trend in inventory ratios during the 1961–1994 or 1980–1994 periods was not very different for work-in-process inventories as compared to materials or finished goods. While work-in-process inventories did not show a higher rate of improvement than materials or finished-goods inventories from 1961 to 1994 (Hypotheses 3(a) and 3(b)), they did not do worse in most cases. There is little evidence that firms reduced materials and finished-goods inventories but not work-in-process inventories.

Explanation of Results: Conjectures

We now speculate on the potential causes for the major findings of the study summarized above. The mixed evidence observed in different sectors and manufacturing stages may be due to several opposing forces, as discussed in §2, which have varying levels of impact on inventory ratios. Practices such as MRP, JIT, quick response, cycle time reduction, and inventory management software may have been adopted more readily and implemented more effectively in certain firms and industries, resulting in differences in improvement across industry sectors. Similar differences may exist in the adoption of mathematical models for determining optimal cycle and safety stock levels (e.g., EOQ type models) across firms and industries.

This may also be true for the forces that *increase* inventory ratios. First, in several industries, the variety of products and processes has increased over time without a proportional increase in demand (Quelch and Kenny 1994). Industries such as electronics have seen explosive growth in the number of new firms and products. In more mature industries such as apparel, firms increase sales by increasing product variety and exploring new markets that often results in higher inventory ratios, especially of finished goods. Second, as U.S. firms have increased their imports in certain industries, material inventories may have increased to compensate for longer and more variable lead times, to buffer against currency fluctuations and other uncertainties.

Finished-goods inventories may not have decreased much, even in some sectors that improved materials and work-in-process inventories for several reasons. First, the production function in a firm, which implements such innovations, has less control over finished-goods inventories that are also determined by inputs from marketing, which typically has little incentive to reduce inventories. Second, finished-goods inventories serve as a buffer against demand uncertainty, and firms may be averse to reducing them so as not to lose sales. Third, as firms aim for high customer service levels and improved responsiveness, they may hold higher inventories or open more warehouses and also may move from make-to-order to make-to-stock production. Also, increase in product variety, which increases finished-goods inventory, may not lead to greater process complexity and raw material variety. Fourth, increasing U.S. exports, which involves less frequent shipments, may have resulted in higher finished-goods inventories. Finally, some manufacturers may have reduced material inventories by pushing the inventory upstream to suppliers, as was rumored in the case of auto manufacturers in the mid-1980s (*Business Week* 1984), which increases finished-goods inventories at the suppliers.

Process and technology innovations often diffuse initially within an industry and then outside the industry, partly due to competitive factors, and this may explain why sectors that reduced inventories lowered them in all three categories. Apparel and leather were the two industries that showed a significant *increasing* trend in inventory ratios in almost all the three types of inventories from 1961–1994. This may be due to the increase in variety and inventories in apparel since the 1960s (Pashigian 1988). However, the apparel sector, and to a lesser extent leather, did show improvement in inventory ratios in the post-1980 period, as compared with the pre-1980 period, which is an encouraging sign.

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5. Limitations and Future Research

There are a number of limitations to this study and its conclusions. First, although we observe evidence of inventory reduction, which may be due to adoption of practices such as JIT and cycle time reduction, it is difficult to establish causality unambiguously. This is because we are dealing with adoption of a system or a set of ideas, so there could be varying degrees of implementation. Also, as discussed earlier, many factors not related to such practices and outside a firm's control also impact inventories.

Second, this research provides evidence only at an aggregate level of the changes in inventory in U.S. industry. There may be considerable differences in inventory performance among industries within a two-digit sector and among firms within an industry. Also, the larger firms would have a greater impact on the industry figures, making the conclusions more applicable to the performance of larger firms in an industry.

A firm-level analysis may yield insights into the true causes of changes in inventory ratios. One could collect data on inventories, output, and factors such as product variety, setup times, and supplier lead times to identify which factors have the greatest impact on inventory ratios. It would also be interesting to investigate the links to quality and customer service, as improvement in quality would reduce inventories while higher customer service levels may result in higher inventory ratios. Further, it would be valuable to explore the linkages between inventory performance and financial performance using firm level data.

This study answers some questions, but raises many more interesting ones that require additional work. Why have materials and work-in-process inventories shown greater improvement than finished-goods inventories? Why have some industry sectors shown significant improvement in inventory ratios, while others have not improved or have shown an increasing trend in inventory ratios? What factors explain the differences in inventory improvement over time across industry sectors? Has increased outsourcing of operations by U.S. firms resulted in lower inventories? Has the increase in variety offered by U.S. manufacturers resulted in higher inventories and inventory ratios? Although there have been a few studies exploring the impact of variety on inventory (Kekre and Srinivasan 1990), there does not appear to be a study of industry-level effects.

Appendix: Data Sources

The data on value added, material cost, and end-of-year inventories at the three manufacturing stages for the years 1961 through 1994 for each of the 20 sectors at the two-digit SIC code level were obtained from the Annual Survey of Manufacturers published by the Census Bureau. The Census Bureau conducts a mail survey of a representative sample of 55,000 manufacturing establishments every year and a complete census of all establishments primarily engaged in manufacturing every five years, in which they request establishments to provide information on key measures of manufacturing activity such as employment, plant-hours, capital expenditures, inventories, value of output, material cost, etc. The definition of the variables used in computing the inventory ratios is given below.

Material Cost

This term refers to direct charges actually paid or payable for items consumed or put into production during the year, including freight charges and other direct charges incurred by the establishment in acquiring these materials.

Value of Shipments

This term refers to the received or receivable net selling values, f.o.b. plant (exclusive of freight and taxes), of all products shipped, both primary and secondary, as well as all miscellaneous receipts, such as receipts for contract work performed for others, installation and repair, sales of scrap, and sales of products bought and resold without further processing. The value of shipments from services may introduce some inaccuracies, but these are likely to be negligible, as services constitute an insignificant proportion of revenues in most manufacturing industry sectors and the proportion of service revenues does not change substantially over time.

Value added = value of shipments − material cost.

Inventories

Respondents are asked to report their current and prior-year end-of-year inventories in dollars at cost or market at all three stages of fabrication. Since a firm can value inventories at cost or market and the valuation method can potentially change from one year to another, this might introduce inaccuracies. However, we expect this error to be insignificant as we find that the percentage of total inventories using a specific valuation method, data on which is reported, has not changed significantly over the years. Also, in its questionnaire, the Census Bureau does not provide any specific suggestions on how a firm should value its inventory at the three manufacturing stages. This may again introduce inaccuracies in the data, but unfortunately it is not possible to overcome this drawback.

Note. Additional details on all aspects of the survey and the data can be found at the Internet site: ⟨http://tier2.census.gov/asm/asminfo.htm⟩.

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