

Inventory Reduction in the Japanese Automotive Sector, 1965-1991

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ABSTRACT

This paper traces the diffusion of “just-in-time” production in the Japanese automotive sector, as reflected by inventory reductions in a sample of 52 suppliers and assemblers. We show that most inventory reductions occurred during a remarkable burst of activity starting in the late 1960s. Companies affiliated with Toyota were the early adopters but were followed very quickly by others in Japan. By the late 1970s nearly all of the firms in the sample had made drastic reductions in inventory. Work-in-process and suppliers’ finished goods fell by nearly two thirds on average.

Keywords:

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1. INTRODUCTION

The concept of “just-in-time” (JIT) or “lean” production has had a revolutionary impact on manufacturing operations in recent years. Pioneered by Toyota in the late 1950s and perfected by the firm over the following decades, the basic JIT system was adopted by most Japanese auto producers in the 1970s and by many North American firms starting in the 1980s (Womack, Jones and Roos, 1990).

A central feature of JIT is the ability to operate with minimal levels of inventory. Inventory reduction exposes defects in the manufacturing process, forcing managers and workers to eliminate sources of production variability and waste. In the automotive supply chain, the relevant inventories are (1) work-in-process (WIP) held internally by parts suppliers and vehicle assemblers, and (2) buffer inventories held between firms.¹ The amount of time required for basic materials to be converted into finished products depends directly on the magnitude of these inventories. Inventory levels are therefore important indicators of production capabilities.

This paper examines the historical process of inventory reduction in the Japanese automotive sector. We use financial accounting data on 52 Japanese auto assemblers and parts suppliers to assess inventory levels over the period from 1965 to 1991. We address questions such as: What has been the magnitude of inventory reductions made by Japanese auto companies since the 1960s? Has JIT adoption been widespread? When did the process of drastic inventory reduction begin, and how quickly was it completed? Moreover, how does Toyota, the pioneering firm, compare with others? Was the JIT system transferred more rapidly or effectively within the Toyota group of companies than outside the group?

¹ In this study these inter-firm inventories are the sum of finished goods held by suppliers and raw materials held by assemblers.

We show that most inventory reductions occurred during a remarkable burst of activity starting in the late 1960s. Companies affiliated with Toyota were the early adopters but were followed very quickly by others in Japan. By the late 1970s, nearly all of the firms in our sample had made drastic reductions in inventory. On average, work-in-process and suppliers' stocks of finished goods fell by nearly two thirds. Subsequent progress has been incremental.

This paper is part of a larger study of inventory reduction and productivity growth in the automotive sector. In this paper we document the timing and magnitude of inventory reduction by Japanese automotive companies. These basic findings are extended in related work. Lieberman and Demeester (1995) analyze the link between WIP inventory and manufacturing productivity; gains in efficiency are found to follow (rather than lead) inventory reduction, with an average lag of about one year. Lieberman and Asaba (1995) consider inventory and productivity differences between the US and Japan; the comparison shows that since the mid-1980s the US automotive assemblers have largely caught up to average Japanese levels of inventory and productivity, but the parts supply sector has stagnated in the US. Helper and Lieberman (1995) evaluate various determinants of inventory levels in the US and Japan; the findings suggest that the managerial influences documented in the present study have been far more important than the effects of technology, interest rates, vertical integration, and other factors.

This paper is organized as follows. Section 2 describes the inventory measures, data, and companies in our sample. Section 3 assesses work-in-process inventory and its reduction over time. Section 4 considers inventories held as a buffer between firms (i.e., supplier finished goods and assembler raw materials). Section 5 concludes the paper with a brief discussion of major findings and implications.

2. DATA AND MEASURES

Companies in the Sample

The sample includes a total of 52 Japanese automotive companies, which can be subdivided as follows. Eight are “core” assemblers.² (A core assembler, such as Nissan or Toyota, is a company that assembles and sells finished automobiles under its own name.) Three are “contract assemblers,” companies that assemble automobiles as subcontractors for the core assemblers. The remaining 41 companies are “first-tier” parts suppliers, i.e., firms that supply parts directly to the assemblers. The sample includes nearly all of the Japanese automobile assemblers and most of the largest parts producers.³ Thus, findings from the sample should be representative of (larger) firms in the Japanese automotive industry.

Company Group Structure

The Keiretsu or group alliance structure of Japanese companies has been widely documented. In this study we test whether the timing and extent of inventory reductions were influenced by the structure of vertical alliances and subcontracting relationships among companies (Asanuma, 1985a, 1985b; Smitka, 1991; Nishiguchi, 1994; Fruin and Nishiguchi, 1994). Accordingly, we assigned many of the firms in the sample to groups, based on the identity of the core assembler at the head of the group. The two primary groups were for Toyota and Nissan. An Isuzu group (Isuzu and 3 suppliers) was also identified but was too small for meaningful analysis.

²The core assemblers are Toyota, Nissan, Honda, Mazda, Daihatsu, Isuzu, Fuji Heavy Industries (marketed as “Subaru” in the United States), and Suzuki. Mitsubishi Motors, which did not report financial data until 1978, is omitted from the sample. The term “core assembler” is due to Asanuma (1989).

³ We attempted to include virtually all firms in the Japanese automotive sector which are listed in the first or second section of the Tokyo Stock exchange. We excluded tire and glass producers, firms with fewer than 200 employees, and firms engaged primarily in the production of heavy trucks.

We assigned parts suppliers to these groups based on their percentage of sales to each of the core assemblers. Table 1 lists the part suppliers in the sample and their percentage of sales to Toyota and Nissan.⁴ Suppliers with more than 35% of their sales to Toyota and less than 20% of sales to Nissan were assigned to the “Toyota group.” Suppliers were assigned to the Nissan and Isuzu groups based on equivalent criteria. These assignments are very similar to other group definitions in the literature (e.g., Dodwell, 1983; Saxonhouse, 1980; Toyo Keizai, 1991). We classified all remaining suppliers as “independents.”⁵ In addition, we assigned the contract assemblers on the basis of widely-recognized affiliations: Toyota Auto Body and Kanto Auto Works as subcontractors to Toyota, and Nissan Shattai as subcontractor to Nissan.⁶

Inventory Data and Measures

The measures in this study are derived from annual accounting data on sales, value-added, and the value of inventories (raw materials, work-in-process, and finished goods), which are reported on a consistent basis by all manufacturing firms in Japan. These data are publicly available and have been compiled by various Japanese organizations.⁷ The annual data correspond to company fiscal years, ending typically in March. Thus, most of the sales reported for a given fiscal year occurred in the previous calendar year.

The inventory data and their interpretation are central to our study. The Japanese annual financial reports give detailed information on year-end inventories, broken down

⁴ The distributions in the table are for 1990, but the percentages have remained fairly stable over time.

⁵ Many of these “independents” nevertheless participate in Toyota’s “Kyohokai” and Nissan’s “Nishiokai” supplier associations, which have broad membership (Sako, 1994). While any cut-off point for defining the Toyota and Nissan groups is arbitrary, our procedure, based on sales distributions, gives assignments similar to those adopted in other studies.

⁶ The specific data used in this study are from the *Analysts' Guide* published annually by the Daiwa Securities Corporation. Detail for 1976 and earlier years was obtained directly from Daiwa Securities.

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by major type (raw materials, work-in-process, and finished goods). Our analysis focuses on (1) work-in-process inventory, and (2) inventories held as a buffer between parts suppliers and final assemblers.

Figure 1 indicates how these inventory levels are related to the speed of materials flow. For simplicity, the Figure shows only a single parts supplier with sales to a single vehicle assembler. The vertical axis represents the accumulation of product value; the horizontal axis gives elapsed time. Inventory stocks are represented as areas under the graph. The work-in-process inventories held by the supplier and by the assembler correspond to the areas under line segments R_1S_1 and R_2S_2 , respectively. The buffer inventory held between the two firms corresponds to the area under the line segment, S_1R_2 .

The Figure implies that inventory levels can be translated into corresponding “cycle times.” The level of work-in-process inventory, for example, is directly related to the time required for materials to move from the beginning to the end of the company’s manufacturing process. Figure 1 shows that the production cycle time is T_{w1} for a supplier with WIP inventory equal to the area under R_1S_1 . This cycle time estimate is based on the assumption that work-in-process accumulates accounting value in a linear fashion as it moves through sequential processing stages at a constant speed.

To allow an intuitive interpretation of the accounting data, we report all inventory levels in terms of corresponding cycle times. Production cycle times were computed in “weeks of WIP,” an estimate of the elapsed time from the beginning to the end of fabrication of a typical product manufactured by the firm. To compute this cycle time, we divided end-of-year WIP by the total sales reported for the previous year, and then multiplied the result by 50 (on the assumption of 50 working weeks per year).⁸

⁸ This approach slightly underestimates the cycle time since it assumes that the areas under line segments R_1S_1 and R_2S_2 are rectangular, rather than trapezoidal. However, estimates based on the trapezoidal assumption were very similar to (and highly correlated with) those presented here. Moreover, our use of a simple WIP/sales ratio allows comparability with similar ratios commonly reported in

As shown in Figure 1, the inter-firm buffer between suppliers and assemblers has two components, whose cycle times were estimated separately. The cycle time for the supplier's inventory buffer, T_{FI} , was computed by dividing the supplier's year-end finished goods inventory by the total sales for the prior year, and multiplying this result by 50. The cycle time for the assembler's inventory buffer, T_{R2} , was computed by dividing the assembler's year-end raw materials inventory by the firm's total raw materials purchases in the prior year, and multiplying by 50.⁹ In any given case, the specific allocation of these inter-firm inventories to the supplier or the assembler may not be meaningful, given that title can be assigned arbitrarily between the two firms.

Two of the assemblers in the sample, Nissan and Fuji Heavy Industries, are diversified into the production of aircraft and missiles, products with very long production cycle times. Line-of-business information from their corporate annual reports (*Yuka Shoken Hokokusho*) was used to adjust the inventory data for these two companies to exclude aerospace manufacturing operations.¹⁰

3. WORK-IN-PROCESS INVENTORY

In this section we document the dramatic reductions in work-in-process inventory associated with the adoption of JIT in the Japanese automotive sector. Toyota and affiliated companies were the early leaders in WIP inventory reduction, but the innovation spread very quickly throughout Japan. Most of the inventory reduction occurred during a decade of intense activity starting in the late 1960s.

industry. Note also that our cycle time estimates are slightly smaller than those obtained using cost of goods sold in the denominator, rather than total sales.

⁹ We assumed that raw materials purchases during the year were equal to sales minus value-added.

¹⁰ Most of the suppliers in the sample are heavily focused on producing high-volume automotive components. Nevertheless, it is likely that some of the inter-firm variation in production cycle times, as estimated below, stems from differing degrees of diversification into low-volume products with high WIP requirements.

Figure 2 plots the work-in-process inventory levels of the core assemblers over the period from 1965 to 1991.¹¹ Toyota and Honda (the latter still primarily a motorcycle producer in the 1960s) maintained the lowest WIP levels throughout the sample period. In the mid-1960s Toyota held about three days of WIP; this was gradually reduced to about one day by the late 1970s. (As described in the previous section, these values can be interpreted as production cycle times.) In the 1960s and early 1970s, many other assemblers, such as Mazda, Daihatsu, Fuji Heavy Industries and Suzuki, held considerably larger WIP inventories, which fluctuated widely from year to year. The manufacturing cycle times corresponding to these WIP inventories sometimes exceeded one month. By the late 1970s, though, the most serious fluctuations were eliminated, and inventory levels began trending downward for all producers except Toyota and Honda, which had made the early reductions. Considerable differences across producers nevertheless remained, with Fuji and Suzuki holding roughly four times as much WIP as Toyota and Honda in the early 1990s.

Figure 3 plots WIP inventory averages for three groups of suppliers: Toyota suppliers, Nissan suppliers, and all others.¹² Some differences are apparent among these groups, but the general pattern is similar: substantial inventory reductions occurred during the relatively brief period from 1968 to 1978, after which inventory levels remained comparatively stable.¹³ The average production cycle time for all parts suppliers in the sample fell from about 2.5 weeks in the late 1960s to about one week by the 1980s.¹⁴ These findings suggest that “lean manufacturing” was almost fully-implemented in the Japanese automotive sector by the early 1980s, when reports of its features first began to emerge in the West (e.g., Shonberger, 1982; Hall, 1983).

¹¹ For simplicity, we omit the 3 contract assemblers.

¹² The 3 Isuzu suppliers were combined with the independents, as no significant differences could be detected.

¹³ For simplicity, Figure 2 omits the three contract assemblers, who cut their WIP inventory in late 1960s.

¹⁴ Although not shown in Figure 3, the degree of variation across firms fell by a comparable margin.

Figure 3 provides evidence, moreover, that the JIT system spread first among Toyota suppliers, and then among the broader class of producers. The WIP inventory of Toyota suppliers was initially higher than the average of all other suppliers in the sample,¹⁵ but starting in 1968 the Toyota group launched dramatic cuts.¹⁶ By the early 1970s the WIP inventory level of Toyota suppliers had fallen significantly below the average for all suppliers. By the mid-1980s, however, the differential between the Toyota and non-Toyota companies virtually disappeared, as lean manufacturing methods diffused throughout the Japanese automotive sector. At the same time, the Toyota group firms began to hold more WIP, to accommodate the demands of Toyota's increased product variety.

We performed statistical tests to verify the differences in group averages plotted in Figure 3. These were implemented by averaging the annual WIP levels for suppliers in each group over three periods (1965-68, 1970-78 and 1980-91), using a t-test to detect significant differences among the groups. The test results are in Table 2. The Toyota suppliers cut their average WIP to a level significantly below that of independents during the 1970-78 period; this difference persisted but was no longer significant (at the .01 level) in the 1980s. Historically, the Nissan suppliers in our sample held less WIP inventory than the Toyota companies or the independents. Adjusting for their low initial base, the tests in Table 2 confirm that the period of major inventory reduction by Nissan suppliers occurred several years later than for the Toyota suppliers.

Algorithm for Identifying Periods of Substantial WIP Reduction

¹⁵ In the mid-1960s the Nissan suppliers in our sample held about half as much WIP, on average, as the Toyota suppliers and independents. Thus, the Nissan suppliers started much "leaner" than the Toyota suppliers. Despite these low initial levels, the Nissan suppliers cut their WIP inventories about 50% further in the mid-1970s.

¹⁶ This timing corresponds roughly with the start of "process-cutting campaign seminars" run by Toyota's supplier association (Kyohokai), which disseminated ideas for "eliminating waste" and implementing the "kanban system." These seminars started in the Tokai district in 1966 and were expanded to suppliers in other regions the following year (Wada, 1991).

Visual inspection of the data revealed that for most companies in the sample there was a well-defined period when most of the inventory reductions occurred. To identify these periods more objectively, we developed and applied a simple algorithm. We then performed a test to determine whether the change in inventory constituted a statistically significant departure from long term trend.

The algorithm for identifying periods of substantial WIP reduction was implemented as follows.¹⁷ For each firm we prepared the time series data on production cycle time, as indicated by the ratio of WIP inventory to sales.¹⁸ We then found the earliest year, if any, where the WIP/sales ratio for the next six years fell below a trajectory involving 4% annual reduction.¹⁹ We defined the following year (i.e., the first year of substantial reduction) as the start of the WIP reduction period. To establish the end of this period, we identified the earliest year for which the cycle time fell within 20% of the average cycle time of the remaining years in the data.²⁰

This algorithm was applied to all companies in the sample. For 6 of the 52 companies, the algorithm was not able to find a meaningful period and it was clear on inspection that those companies did not display a period of substantial cycle time reduction. Presumably, they had not yet adopted JIT. Figure 4 shows the results of this search for company specific JIT adoption periods. The supplier companies are grouped

¹⁷ We experimented with several algorithms, which gave similar results. The procedure reported here is the simplest of the algorithms we tested.

¹⁸ To reduce the noise level of the data, we computed a moving average across each two-year period. Hence, the data point for year t is the average of the WIP/sales ratio in year t and year $t-1$ (except for the first year of data).

¹⁹ In Lieberman and Demeester (1995) we also apply a more stringent criterion of 8% annual reduction. All but two of the firms that met the 4% criterion met the more stringent criterion as well. We report the results for the 4% criterion, as the periods identified by the algorithm tend to be longer.

²⁰ For any given company, the period of substantial inventory reduction identified by this algorithm may not correspond exactly to the period when a formal program of JIT was implemented. For example, some preliminary cuts in inventory may be necessary or desirable before a kanban system can be used for production scheduling. Indeed, a comparison with the dates of kanban adoption identified by Shiomi (1985) in his questionnaire survey of Toyota suppliers suggests that this was often the case. Nevertheless, the inventory reduction periods identified by the algorithm are likely to be strongly correlated with those of formal JIT adoption.

to reflect their links with the major assemblers. Within each group, the earlier adopters are listed first.

Figure 4 shows variation in the length of the adoption period, and more interestingly, in the starting date of the adoption. Most firms began to adopt JIT during the 1970s and completed the basic process by the early 1980s. Among the assemblers, Toyota, Honda and Nissan began cutting in-process inventories during the 1960s or earlier; the smaller assemblers followed by 1975.²¹

Moreover, it can be seen that companies in the Toyota group tended to cut their inventories several years earlier than companies in the Nissan or Isuzu groups or the independents. Within the Toyota group, the three earliest adopters maintained very close ownership and sales ties with Toyota: Kanto and Toyota Body are Toyota's two largest contract assemblers, while Aisin Seiki is a closely linked supplier of primary components. Only one of the Toyota group companies in the sample failed to make substantial inventory reductions during the period studied.²²

For firms that demonstrated a period of substantial WIP reduction, as identified by the algorithm, we performed an additional test to determine whether this reduction represented a statistically significant departure from the long-term trend.²³ For 40 companies, this difference was statistically significant at the .05 level. The companies for which significance was obtained are indicated by an asterisk in Figure 4.

²¹ For Toyota and Nissan, we obtained inventory data going back to the early 1950s. Using these data, we identified 1958 as the start of Toyota's WIP reduction period, which is consistent with various accounts in the literature. For Nissan, we identified 1966 as the start of WIP reduction. (However, Nissan's reduction did not prove statistically significant, as discussed below, a finding consistent with the fact that Nissan never successfully adopted a Toyota-style approach to production control (Cusumano, 1985). In the case of Honda, we inferred an early adoption date from the fact that Honda's inventory levels were below those of Toyota in the earliest years of data available.

²² Chuo Spring did not begin implementing the kanban system for production control until the 1990s, well after most other Toyota suppliers. (Interview at Chuo Spring, September 8, 1992.)

²³ For each company we used a one-tailed t-test to determine whether the annual rates of inventory reduction were significantly greater during the period identified by the algorithm, as compared with the other years of data coverage.

We computed the average reduction in manufacturing cycle time for the core assemblers and suppliers that were found to have significant WIP reduction periods.²⁴ The average cycle time of assemblers fell from 2.0 weeks to 0.7 weeks, while the average cycle time of parts suppliers fell from 2.6 weeks to 0.9 weeks.²⁵

4. INTER-FIRM INVENTORIES

As illustrated previously in Figure 1, the inter-firm inventories in our sample consist of finished goods (FGI) held by suppliers and raw materials held by assemblers. The total elapsed time between completion of a component part at the supplier stage and its insertion in a vehicle at the assembly stage can be roughly estimated by adding these two inventories.

Consider, first, the stocks of finished goods held by suppliers.²⁶ Figure 5 plots the magnitude of suppliers' finished goods inventories over the period from 1965 to 1991. The pattern of reduction is similar to that shown previously for WIP. On average across the sample, supplier FGI fell from nearly three weeks supply in the 1960s to about one week in the 1980s. The most dramatic reductions took place during the decade from 1968 to 1978.

As with WIP, the move to cut finished goods inventory began with the Toyota suppliers but spread quickly throughout the Japanese automotive sector. In the mid-1960s Toyota suppliers maintained finished goods inventory levels similar to those of other suppliers in the sample. Over the next decade, from the late 1960s to the late

²⁴ Toyota and Honda are excluded from the assemblers, as their WIP reduction began prior to 1965.

²⁵ Moreover, the variability in cycle time fell an even greater margin: the standard deviation of cycle time fell to one-fifth its previous value (from 0.48 to 0.10) in the case of assemblers, and about one-third (from 0.36 to 0.13) in the case of parts suppliers.

²⁶ Two parts suppliers, Topre and Press Kogyo, report no holdings of finished goods inventory during the sample period. We excluded these companies, as presumably, the value of their output is transferred immediately to assemblers.

1970s, the Toyota suppliers cut their FGI by about two-thirds. These suppliers continued to make further, incremental reductions through the 1980s (unlike the case with WIP inventory, which increased for Toyota suppliers during the 1980s). Hence, a significant differential in finished goods inventory between Toyota suppliers and others persisted into the 1990s. By 1991, Toyota suppliers held about 3 days of finished goods, Nissan suppliers about four days, and independents about one week.²⁷

Table 3 documents the statistical significance of these finished goods inventory differentials. During the mid-1960s there was no significant difference among Toyota, Nissan and independent suppliers. For years after 1970, however, the Toyota suppliers held significantly lower finished goods inventories than independents.

We applied the algorithm described in Section 3 to identify periods of substantial reduction in FGI by each company.²⁸ Figure 6 shows these periods, which were detected for all but one supplier. The periods proved statistically significant (based on the t-test described in Section 3) for all but seven of the companies. The Figure shows that on average, the Toyota suppliers cut FGI several years earlier than others.

Supplier FGI constitutes only one component of the inventory buffer between firms; assemblers' stocks of raw materials must also be considered. Figure 5 shows the raw materials held by assemblers at the end of each fiscal year. These raw materials inventories tended to be smaller than the finished goods inventories held by suppliers. On average, assemblers held about half a week of raw materials inventory, with little change over time. The largest raw materials inventories were held by Isuzu, Fuji, and Nissan; the smallest by Daihatsu, Toyota, Suzuki, and Mazda.

Combining the supplier finished goods inventories (Figure 5) with the assemblers' raw materials inventories (Figure 7) reveals that most reductions in inter-firm inventory

²⁷ The finished goods inventory held by suppliers to service Toyota is probably less than the estimate given here, given that the suppliers also deliver to other assemblers. One reason for the very low inter-firm buffers in the Toyota group is that most Toyota suppliers are located near Toyota's assembly plants.

²⁸ In this case we applied the algorithm to the time series data on finished goods inventory / sales, rather than work-in-process inventory.

were made by suppliers. There is certainly no evidence supporting the allegation, common in the US, that as assemblers adopt JIT, they cut their own inventories but force suppliers to hold more finished goods. By the end of the sample period, the total inter-firm buffer was approximately four days for the Toyota group (three days supplier finished goods plus one day Toyota raw materials) and seven days for the Nissan group (four days supplier finished goods plus three days Nissan raw materials).

Figure 8 compares the start dates for WIP and FGI reduction, as identified for parts suppliers using the algorithm described in Section 3. Firms below the 45-degree line began cutting FGI before cutting WIP; firms above the line did the opposite. Firms plotted at the extremes failed to exhibit a period of substantial reduction in either FGI or WIP (or both). The Figure shows that all nine of the Toyota parts suppliers began cutting FGI by 1970, whereas only about one-third of the other part suppliers did so. Within the Toyota group, the earliest adopters began cutting WIP and FGI simultaneously, later adopters cut finished goods first, followed by WIP. For the non-Toyota suppliers, no similar tendency is apparent with respect to the sequence of inventory reduction.

5. CONCLUSIONS

Using financial accounting data on inventory holdings, we have traced the diffusion of JIT, or “lean manufacturing,” through the Japanese automotive sector. Companies affiliated with Toyota were the early adopters of this important managerial innovation but were followed very quickly by others in Japan. Over the period of about a decade from the late 1960s to the late 1970s, auto assemblers and parts suppliers made dramatic cuts in their work-in-process inventories. At the same time, suppliers sharply cut their stocks of finished goods. Production cycle times fell by about two-thirds, on average, while suppliers cut their finished goods inventories by a similar margin.

This rapid diffusion of JIT methods in Japan contrasts with a much slower diffusion process in the US, where many automotive suppliers have yet to adopt the basic features of the JIT system (Helper, 1991; Cusumano, 1985; Lieberman and Asaba, 1995). The speed of Japanese adoption reflects the rapid flow of technical information in Japan. Early adoption by Toyota affiliates points to the role of assembler-supplier networks as a vehicle for technology diffusion (Sako, 1994). However, the rapid diffusion outside the Toyota group indicates that these network boundaries are highly permeable, despite the low mobility of workers among companies in Japan.

Moreover, the data show the central role played by suppliers in the inventory reduction process. On average, suppliers cut work-in-process inventories by a slightly greater margin than assemblers, and suppliers made substantial reductions even when their most closely affiliated assembler did not. There is no evidence supporting the allegation, common in the US, that assemblers pushed inventory requirements backward onto suppliers; if anything, the opposite seems to have occurred. In general, the findings are consistent with a cooperative relationship between assemblers and suppliers, as documented in other studies (e.g., Asanuma, 1985a,b; Nishiguchi, 1994).

The pattern of inventory reductions documented here, while of historic interest, may also serve as a potential benchmark for companies that are beginning to adopt JIT production methods. We have provided comparative information on inventory levels and the speed and extent of inventory reduction typical of larger firms during the adoption period in Japan.

Finally, we have demonstrated a simple methodology for identifying periods of dramatic change in firms' accounting ratios. We have used this methodology to detect periods of inventory reduction. The approach should be equally applicable in other research studies where objective procedures are required to identify periods of company transformation and restructuring activity.

REFERENCES

- Asanuma, B., "The Organization of Parts Purchases in the Japanese Automotive Industry," *Japanese Economic Studies*, vol. 13:4, Summer 1985, pp. 32-53.
- Asanuma, B., "The Contractual Framework for Parts Supply in the Japanese Automotive Industry," *Japanese Economic Studies*, vol. 13:4, Summer 1985, pp. 54-78.
- Asanuma, B., "Manufacturer-Supplier Relationships in Japan and the Concept of Relation-Specific Skill," *Journal of the Japanese and International Economies*, vol. 3, March 1989, pp. 1-30.
- Cusumano, M. A., *The Japanese Automobile Industry: Technology & Management at Nissan and Toyota*, Harvard University Press, Cambridge, 1985.
- Daiwa Securities Research Institute, *Analyst's Guide*. Tokyo, Japan, annual issues.
- Fruin, W. M. and T. Nishiguchi, "Supplying the Toyota Production System," in B. Kogut, ed., *Country Competitiveness*, Oxford University Press, 1994.
- Hall, R. W., *Zero Inventories*. Homewood, IL: Dow Jones-Irwin, 1983.
- Helper, S., "How Much Has Really Changed Between U.S. Automakers and Their Suppliers?" *Sloan Management Review*, Summer 1991, pp., 15-28.
- Helper and Lieberman, "The Empirical Determinants of Firms' Inventory Holdings: Evidence from the US and Japanese Automotive Supply Sectors," mimeo, 1995.
- Lieberman, M. B. and L. Demeester, , "Inventory Reduction and Productivity Growth: Evidence from the Japanese Automotive Sector," mimeo, 1995.
- Lieberman and Asaba, "Productivity and Inventory Comparisions of Japanese and US Automotive Manufactuers," mimeo, 1995.
- Nishiguchi, T., *Strategic Industrial Sourcing: The Japanese Advantage*. New York: Oxford University Press, 1994.
- Sako, M., "Kyoryokukai (Suppliers' Association) in the Japanese Auto Industry: Collective Action for Technology Diffusion," mimeo, London School of Economics and Political Science, June 1994.
- Saxonhouse, G. R., *Economic Statistics and Information Concerning the Japanese Auto Industry*, National Technical Information Service, Springfield, VA, 1980.

- Shiomi, N., "Kigyo Group no Kanri teki Togo," (Management Integration of a Corporate Group), *Oikonomika*, vol. 22:1, June 1985.
- Schonberger, R. J., *Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity*. New York: Free Press, 1982.
- Smitka, M. J., *Competitive Ties: Subcontracting in the Japanese Automotive Industry*, Columbia University Press, New York, 1991.
- Toyo Keizai, Inc., *Japan Company Handbook*. Tokyo, Japan, 1991.
- Wada, K., "The Development of Tiered Inter-firm Relationships in the Automotive Industry: A Case Study of Toyota Motor Corporation," *Japanese Yearbook on Business History*, vol. 8, 1991.
- Womack, J. P., D. T. Jones and D. Roos, *The Machine that Changed the World: The Story of Lean Production*. Rawson Associates, 1990.

