Japanese manufacturing methods at U.S. manufacturing plants: empirical evidence

MASAO NAKAMURA University of British Columbia
SADAO SAKAKIBARA Keio University
ROGER G. SCHROEDER University of Minnesota

Some Japanese manufacturing industries, such as the auto, electronics and machinery industries, achieved high levels of international competitiveness in the 1980s. Consequently their manufacturing and business practices attracted the attention of North American manufacturers (Nakamura and Vertinsky 1994). It is possible that firms' difficulties in dealing with external market related problems and associated legal restrictions over which firms have little control have prevented certain Japanese business practices, such as supplier-manufacturer relationships and corporate control practices, from being adopted by many North American firms to a significant degree. On the other hand U.S. manufacturing firms do have control over their production methods and, to a lesser degree, the industrial relations on their own shop floors. It is Japanese business practices in these areas that U.S. manufacturing firms spent substantial amounts of resources to transplant to their U.S. operations in the 1980s.

There is considerable anecdotal evidence that transfer of Japanese production methods has had significant impacts on the performance of U.S. manufacturing plants (e.g. Krafcik 1988). There is, however, relatively little empirical evidence based on a broad sample of plants and workers. The purpose of this paper is to fill in this gap in the literature.

I. JAPANESE MANUFACTURING METHODS

In designing its production system in the late 1950s, Toyota Motor Company decided that the type of mass production system employed, for example, by General Motors could not be implemented in Japan because the small Japanese demand for automobiles would not allow the U.S. style mass production system to achieve scale economies required for production efficiency. Toyota instead chose to develop a production system which

Canadian Journal of Economics Revue canadienne d'Economique, XXIX, Special Issue
April avril 1996. Printed in Canada Imprimé au Canada

0008-4085 / 96 / S468-474 $1.50

minimizes the total production cost while scale economies could be achieved by producing many differentiated products on the same production line.

Toyota perfected the Toyota Production System, also called the "Kanban" or just-in-time (JIT) system, in the early 1970s. The JIT production system requires that all necessary parts and/or semi-products be delivered to where they are needed, as they are needed, and in the quantities needed (Ohno 1978 and Schroeder 1993, Ch. 18). After the first oil shock, Toyota emerged as the leading Japanese auto manufacturer. Toyota disseminated their JIT production management technology to other Japanese auto makers in the late 1970s. By the end of the 1970s all Japanese automakers had adopted JIT. In addition JIT has been widely adopted in various forms by many Japanese and North American manufacturers in different industries.

Quality control is closely associated with JIT since defective parts in production processes disturb the continuous flow of products in process. JIT also requires reductions in machine setup and repair time. A team approach and multi-skilled workers are considered to help to reduce setup and repair time. In general, the human factor is important for a successful implementation of JIT.

In the Japanese context, JIT is closely tied to Japanese industrial relations practices such as long-term employment, investment in firm-specific human capital, job rotations, multi-skilled workers, and knowledge sharing on the shop floor (Nakamura and Nakamura 1991 and Nakamura 1993). In transferring JIT to the United States, the U.S. manufacturers distilled and implemented only those aspects of JIT which they deemed essential to improve their production efficiency.

It is also important to recognize that the marginal cost of production associated with JIT and other Japanese manufacturing practices is not likely to be higher than the marginal cost associated with alternative manufacturing practices such as materials requirements planning methods. Nevertheless, investment in research and development and in capital equipment for full implementation of JIT can be substantial, since full utilization of teams and multi-skilled worker capabilities usually requires re-designing of production equipment and its layout.

II. EMPIRICAL RESULTS

JIT technologies are thought to be particularly effective for repetitive operations (Aoki 1988 and Schroeder 1993) which are found, for example, in machinery, electronics and auto parts industries. In these industries the following performance measures are commonly used for assessing a plant's manufacturing operations: (1) average percentage downtime of machines due to failure during a normal shift (%downtime); (2) percentage of products which pass final inspection without rework (%passed); (3) percentage of orders that are shipped on time (%shipped); (4) average total cycle time measured in days from the receipt of raw materials until a customer receives the product (cycle time); (5) average lead time measured in days from the receipt of each order until the product is shipped (lead time); and (6) the ratio of total inventory to sales (inv).

For manufacturing industries with significant repetitive operations, these plant performance measures directly affect firm performance. These plant performance measures are regressed on plant manufacturing policy dummy variables, workers' perception variables, plant dummies, and industry dummies. The most important policy variables in this study are JIT related (JIT with limited scope and plant-wide full JIT) variables. Successful implementation of JIT requires, for instance, official quality control programs and worker participation, but the latter two alone without a JIT framework for manufacturing do not necessarily lead to competitive manufacturing operations (Sakakibara, Flynn, Schroeder and Morris 1993 and Sakakibara, Flynn and Schroeder 1994).

We report our estimation results with and without quality (q) related policy variables (limited scope q and plant-wide full q). Workers' perception variables are included in our specifications to control for the effects of certain shop floor practices and are scaled as follows: from a value of 1 for "I strongly disagree" to a value of 5 for "I strongly agree." These perception variables are workers' responses with respect to the following questions: (1) employees receive training to perform multiple tasks (multitask); (2) charts plotting the frequency of machine breakdowns are posted on the shop floor (breakdown charts); (3) promotion implies team participation and experience with the firm (team); and (4) all employees believe that it is their responsibility to improve quality in their plant (q-imp).

Our sample consists of 40 plants which were operational in 1988 and 1989 in the U.S. machinery, electronics and auto parts industries. No large integrated or diversified assembler firms are included. Of the 40 sampled plants, 13 are owned by Japanese firms, 15 are U.S. owned plants which are regarded as having progressive world class manufacturing operations, and the remaining 12 plants are regarded as traditional U.S. owned manufacturing plants.

Our estimation results are presented in table 1. The policy variables of our primary interest, full JIT and limited JIT, are often statistically significant

TABLE 1
The effects of JIT and other variables on plant performance measures[a]

	Performance measures											
	%downtime		%passed		%shipment		cycle time		lead time		inv	
constant	14.3***[b]	15.3***	90.8***	99.1***	69.5***	54.1***	169.4***	124.4***	68.3**	87.8***	.077	.052
	(4.16)	(4.87)	(20.2)	(20.5)	(4.38)	(2.64)	(5.29)	(3.19)	(2.01)	(3.11)	(1.16)	(.82)
JIT:limited	-9.79***	-9.95***	2.59	5.42**	13.1*	9.78	-59.6***	-72.0***	-55.6*	-59.5	.041	.069
	(3.34)	(3.78)	(1.04)	(2.19)	(1.89)	(1.48)	(3.65)	(3.64)	(1.86)	(1.60)	(.94)	(1.13)
JIT:full	-10.9***	-11.2***	4.42***	7.15***	15.1**	12.1*	-89.0***	-100.3***	-45.8**	-50.4*	-.102**	-.129**
	(3.94)	(4.36)	(2.28)	(3.51)	(2.28)	(1.68)	(5.11)	(4.94)	(2.07)	(1.80)	(2.36)	(2.09)
q:limited	--	-4.50***	--	-8.78***	--	15.5	--	56.8**	--	-45.1	--	.047
		(2.72)		(3.68)		(1.12)		(2.05)		(1.62)		(.59)
q:full	--	--	--	-10.6***	--	9.78	--	50.9*	--	-1.07	--	.057
				(4.63)		(1.48)		(1.91)		(0.3)		(1.08)
multitask	-1.46**	-1.45**	.934	.864	-.033	-0.80	8.99	9.10*	-14.9**	-14.0**	.018	.015
	(2.36)	(2.36)	(1.07)	(1.04)	(.01)	(.03)	(1.53)	(1.66)	(1.94)	(2.00)	(1.23)	(.82)
breakdown charts	.725	.650	2.03***	1.82***	3.37*	3.73*	-12.8**	-11.7**	-.459	-.732	.015	.012
	(1.27)	(1.17)	(3.06)	(2.67)	(1.67)	(1.87)	(2.51)	(2.42)	(.09)	(.15)	(.77)	(.62)
team	.608	.659	-1.09	-1.02	-1.53	-1.70	.380	-.30	14.9	15.0*	-.020	-.02
	(.94)	(1.05)	(1.06)	(1.03)	(.58)	(.62)	(.05)	(.04)	(1.62)	(1.65)	(1.27)	(1.47)
q-imp	1.90***	2.10***	-1.80**	-2.01***	-2.15	-1.93	-2.01	-.97	19.6**	20.5**	.012	.008
	(3.93)	(4.74)	(2.40)	(2.63)	(1.24)	(1.19)	(.43)	(.21)	(2.54)	(2.44)	(.81)	(.54)

TABLE 1 (Continued)

world class	-1.76	-3.15**	-6.64***	-6.04***	4.37	6.04	-13.2	-12.1	-59.5***	-74.5***	.045	.084
	(1.59)	(2.49)	(3.07)	(2.57)	(.96)	(1.29)	(1.08)	(1.08)	(3.34)	(3.20)	(.75)	(1.25)
traditional	--	--	--	--	--	--	--	--	--	--	--	--
J-transplant	1.13	.448	-.879	-.505	7.88	9.30	-1.38	.00	-23.5	-34.9	-.037	-.015
	(.59)	(.24)	(.48)	(.30)	(1.23)	(1.56)	(.09)	(.00)	(1.02)	(1.41)	(.92)	(.42)
machinery	1.18	.658	-7.59***	-6.88***	-6.71	-6.10	10.7	-11.5	23.2	14.1	.135**	.160***
	(.95)	(.55)	(3.98)	(3.39)	(1.24)	(1.21)	(.81)	(.91)	(1.30)	(.92)	(2.10)	(.27)
electronics	--	--	--	--	--	--	--	--	--	--	--	--
auto parts	2.70***	2.31**	1.55	1.96	4.38	4.33	-25.8***	-27.4***	-25.0*	-28.2**	-.008	.013
	(2.62)	(2.31)	(.93)	(1.20)	(1.31)	(1.25)	(2.31)	(2.60)	(1.88)	(2.15)	(.25)	(.33)
R^2	.430	.473	.392	.444	.234	.271	.414	.444	.343	.371	.196	.242
N	93	93	102	102	99	99	102	102	102	102	97	97

[a] See the text for the definitions of the performance measures and included explanatory variables. Generally, good production management is associated with lower values for %downtime, cycle time, lead time and inv and with higher values for %passed and %shipment.

[b] Numbers in parentheses are heteroscedasticity-corrected t ratios. One, two and three asterisks imply 10%, 5% and 1% significance levels, respectively.

and are found to improve plant performance measures. In particular, full JIT is significant in all equations. These results suggest that implementation of JIT, in even a limited form, leads to significant improvements in the plant performance measures we consider here. On the other hand the effects of plant wide quality improvement programs (full q) are limited to increasing cycle time and decreasing %passed. These results seem to suggest that the plant management is often willing to solve quality problems even though doing so does not contribute to short run plant performance. This conclusion is also supported by the significant effects of q-imp on %downtime, %passed and lead time since q-imp is found to adversely affect these measures of performance.

Multitask which improves work efficiency is found to reduce downtime and lead time. Other performance measures are not significantly affected by this variable. Breakdown charts which measure the degree of information exchange on the shop floor are found to significantly reduce cycle time and increase %passed and %shipped. Our team variable does not have much effect on plant performance.

Japanese transplants are not distinguishable from U.S. traditional plants (omitted category), but significantly negative U.S. world class (WC) manufacturing plant dummies may imply that there is some unexplainable difference between traditional and WC manufacturers. There is also considerable industry related variation in plant performance relative to the electronics industry (omitted category). The machinery industry performs poorly in %passed, and the auto parts industry, which suffers from a slightly higher %downtime than the other two industries, outperforms the other industries by a wide margin in terms of cycle time and lead time.

We have provided empirical evidence using data on broadly chosen U.S. manufacturing plants that JIT as a company policy can indeed improve various measures of manufacturing plant performance. In our full paper we also present empirical evidence that worker cooperation and pride, long recognized as important ingredients for a successful implementation of JIT, can be enhanced by involving workers in quality awareness programs and by the presence of the plant manager on the shop floor as is the practice in many Japanese manufacturing plants.

NOTES

The authors are affiliated, respectively, with the Institute of Asian Research and Faculties of Commerce and Applied Science, UBC; the Faculty of Business and Commerce, Keio University; and the Carlson School of

Management, University of Minnesota.

REFERENCES

Aoki, M., (1988) *Information, Incentives, and Bargaining in the Japanese Economy* (Cambridge)

Krafcik, J.F. (1988) 'Triumph of the lean production system.' *Sloan Management Review*, fall

Nakamura, M. (1993) 'Japanese industrial relations in an international business environment.' *North American Journal of Economics and Finance* 4, 225-51

Nakamura, M., and A. Nakamura (1991) 'Risk behavior and the determinants of bonus versus regular pay in Japan.' *Journal of the Japanese and International Economies* 5, 140-59

Nakamura, M., and I. Vertinsky (1994) *Japanese Economic Policies and Growth: Implications for Businesses in Canada and North America* (University of Alberta/UBC Press)

Ohno, T. (1978) *Toyota Production System: Beyond Large-Scale Production* (Tokyo: Diamond), English translation, Productivity Press, 1988

Sakakibara, S., B.B. Flynn, R.G. Schroeder, and W.T. Morris (1993) 'The impact of just-in-time manufacturing.' Carlson School of Management, University of Minnesota

Sakakibara, S., B.B. Flynn, and R.G. Schroeder (1994) 'A framework and measurement instrument for just-in-time manufacturing.' *Production and Operations Management*, forthcoming

Schroeder, R.G. (1993) *Operations Management: Decision Making in the Operations Function*, 4th edition (New York: McGraw-Hill)